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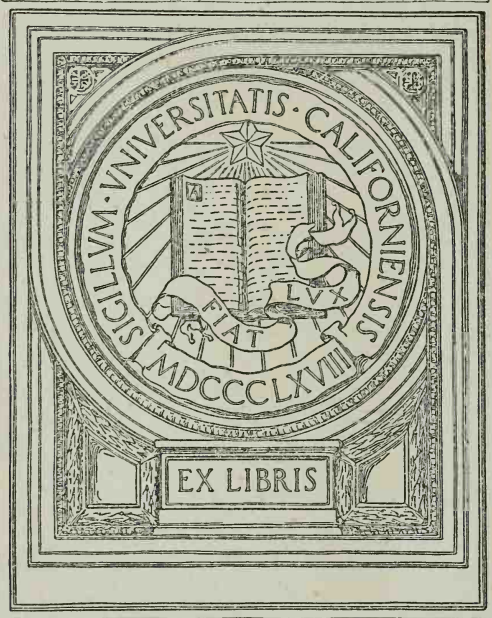

James F. Rinehart

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1927-

ROENTGEN INTERPRETATION

A MANUAL

FOR STUDENTS AND PRACTITIONERS

BY

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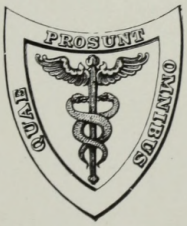

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PREFACE TO THE SECOND EDITION.

We have taken advantage of the opportunity offered by a new edition to correct some of the defects of the previous one and to revise and enlarge the material throughout the book.

It is our hope that it will prove to be of some practical use to those undertaking this fascinating field of medicine.

G. W. H.
H. E. R.

PREFACE TO THE FIRST EDITION.

It is hoped that this book will prove of practical aid to those in search of a working knowledge of roentgen interpretation. The intention has been to present the essentials in a comprehensive form. More detailed information may be secured through the references to the recent literature, which will be found at the end of the chapters.

The illustrations have been chosen as types of lesions, or as momentary phases of constantly changing and extremely variable processes. The beginner should not attempt to make diagnoses from them by comparison with his own plates.

The necessity of a medical training as a prerequisite in this field is, of course, recognized, but the particular importance of thorough grounding in pathology is not always sufficiently plain. In attempting to study gross changes by means of shadows, a knowledge of pathology is as essential to the roentgenologist as anatomy to the surgeon.

G. W. H.
H. E. R.

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ROENTGEN INTERPRETATION.

INTRODUCTION.

It cannot be too strongly emphasized in the beginning that roentgen images are shadowgraphs; that they are the record of the varying opacities through which a bundle of rays has passed; and that they are subject to the possibility of erroneous deductions consequent upon the fact that they are shadows. Objects are visible when they differ in density from their surroundings. The outline of the heart is distinct against the air-filled lung about it while the uterus of similar density is lost in the shadow of the pelvis.

Furthermore, the roentgenogram is a projection on a flat surface of everything in every plane between the plate and the tube's target. It must not be forgotten that in addition to the patient this includes opaque objects upon the filters, the clothing of the patient and the envelope of the plate. The shadow of a rounded bone with ridges on opposite sides will appear on the plate as a flat image with the ridges lying side by side. It is therefore essential for the roentgenologist to have a thorough knowledge of the projected appearance of anatomical structures, so that he may be able to visualize from a flat plate the relative depth of objects seen upon it. The study of stereoscopic plates is of great value in this connection.

Another source of possible error lies in the fact that we commonly employ divergent rays. Parallel rays are seldom made use of in roentgenology except in determinations of the size of the heart. Ordinarily plates are produced by a tube which is relatively close to the plate; therefore we are using divergent rays, and the images of objects in their path will be distorted according to their position with reference to the plate. Objects in contact with the plate give an image of actual size and are sharply outlined. As they recede from it their outline becomes more hazy and their size increases. When a wide field of illumination is employed the central rays are practically parallel, but at the margins of the field they strike

obliquely, giving a markedly distorted image. It is customary, therefore, to limit the rays as much as possible to the central bundle by the use of diaphragms and to place the area under observation as closely as possible to the plate. There is an additional advantage to be gained in the employment of small diaphragms because the plates are brighter. Anything in the path of the rays gives off secondary radiation and scatters the primary beam just as light is scattered by fog. This secondary and scattered radiation tends to obscure the image cast by the primary rays, therefore the area of tissues exposed to the rays should be as limited as possible.

One view is an isolated observation and is perhaps less to be relied upon than a single observation in any field of medicine. As far as possible, plates should always be secured in planes at right angles to each other, and often additional plates at various angles will establish a diagnosis which would otherwise be impossible. This is particularly important in studies of the skull, spine and the neighborhood of joints.

In conclusion, there are several axioms which form the basis for successful roentgen interpretation:

1. Do not attempt to include everything on one plate; several small ones are always preferable.
2. Do not make a diagnosis before everything possible has been done; thoroughness is essential.
3. Be familiar with the projected appearance of normal structures.
4. Use routine positions for all examinations as far as possible.
5. Do not give opinions on poor plates.

In order to avoid confusion in the use of the terms "increased" and "diminished" density, it should be understood that when they occur in this text they apply to the tissues of the patient. These expressions may be employed to designate the thickness of the silver deposit on the roentgenogram—the actual density in the image of the emulsion—which necessarily is reciprocal to the density of the patient. So, in this book, "increased density" means the loss of transparency to the rays and light areas on the roentgenogram. "Diminished density" means increased radiability and darkening of the plate. Most of the illustrations are positives of the original roentgen negatives and therefore their values are the opposites of those in the plates.

CHAPTER I.

CONFUSING SHADOWS AND ARTEFACTS.

THERE are many shadows in normal plates which may cause errors in interpretation. Their significance is obvious when they have once been recognized, but the beginner is prone to attach undue importance to them, particularly when they occur in regions to which his attention has been directed by the clinical picture. In case of doubt it is always wise to take plates of the corresponding parts or to compare them with other plates of the same region in other individuals.

Lines Mistaken for Fractures.—The most common error here occurs with the epiphyseal lines, which appear as a definite break in the continuity of the bones. It is therefore essential for the roentgenologist to have a complete knowledge of the time of appearance of the various centers of ossification, the location of epiphyseal lines and the approximate age at which they disappear.

When one bone overlaps another or the edge of a muscle bundle crosses a bone there may be a thin, sharply drawn black line which at times resembles a fracture. This appearance is often noticed in the transverse processes of the lumbar vertebræ where the inner margin of the psoas muscle crosses them.

A third possibility of error is furnished by the markings due to bloodvessels which are particularly evident in the skull where the course of the middle meningeal artery appears as a tortuous groove behind the coronal suture and is more or less sharply outlined. The venous channels in the diploe of the skull provide another set of dark lines, irregular in their course and indefinite in outline. In the long bones there is ordinarily a definite groove where the nutrient artery enters the shaft, which may be mistaken for a fracture when seen in profile, as, for example, in the phalanges of the hands and feet. It is well, therefore, to be familiar with the anatomy of these vessels.

An accurate knowledge of the location and appearance of the sutures of the skull will prevent their misinterpretation, a common error particularly with the parietomastoid, which is often called a fracture of the base.

The characteristics of a fracture line which are usually sufficient to identify it are that it is a dense black with sharply cut margins; its course is usually irregular and, particularly in the skull, at variance with that of the bloodvessel markings.

Roughening of the Margins of Bones Mistaken for Periostitis.—Frequently there is a thin plate of bone extending out on the intermuscular septum, as, for example, between the tibia and fibula, or radius and ulna, which seen in profile is quite suggestive of periosteal proliferation, and one must be careful to differentiate this condition from a true periostitis.

A similar process is liable to occur at the attachment of tendons, such as the tendo Achillis, the triceps, along the margin of the iliac crests, along the linea aspera of the femur and about the external occipital protuberances of the skull. There is very commonly a roughening and slight proliferation along the margins of the phalanges of the hands, which is without significance. The flange behind the intercostal groove on the inferior margin of the ribs posteriorly is often exaggerated and suggests a periostitis. The tibial tubercle may be somewhat widened and its lateral margin projected outside the outer border of the tibia a short distance below the head; it is frequently mistaken for a localized proliferation of periosteum. There is normally a variable amount of roughening on the inferior margin of the pubes and ischial tuberosities.

A true periostitis consists of more or less extensive deposit of new bone upon a normal appearing cortex. This deposit may be laid down in multiple thin lamellæ, giving it a delicately stratified structure, which is a form frequently seen in lues; or it may be a low irregular fringe, as seen in some forms of osteomyelitis.

Calcifications.—Calcium salts cast a dense shadow wherever they occur. They have an extensive distribution in the body outside of the bony structures. Cartilage is perhaps the tissue in which calcium salts are most prone to be deposited. This is seen in the costal cartilages, where the deposit usually occurs upon the surface of the cartilage in the form of irregular plaques appearing in chest, spine, gall-bladder and kidney plates. These shadows are without significance and their nature is, as a rule, easily determined.

Calcification also occurs in the same manner in the cartilages of the larynx and is easily recognizable in lateral views of the neck. In anteroposterior views of this region, however, they are projected in the region of the lateral masses of the cervical vertebræ and have

been mistaken for hypertrophic changes in the spine or calcified vertebral arteries.

Another common seat of calcification is old tuberculous, foci, examples of which are the irregular masses in bronchial glands, the characteristic agglomerations of small masses which produce the irregular mulberry-like shadows typical of tuberculous glands, which are frequently found in the neck and throughout the mesentery in the abdomen. They are usually multiple. Small, rounded, dense

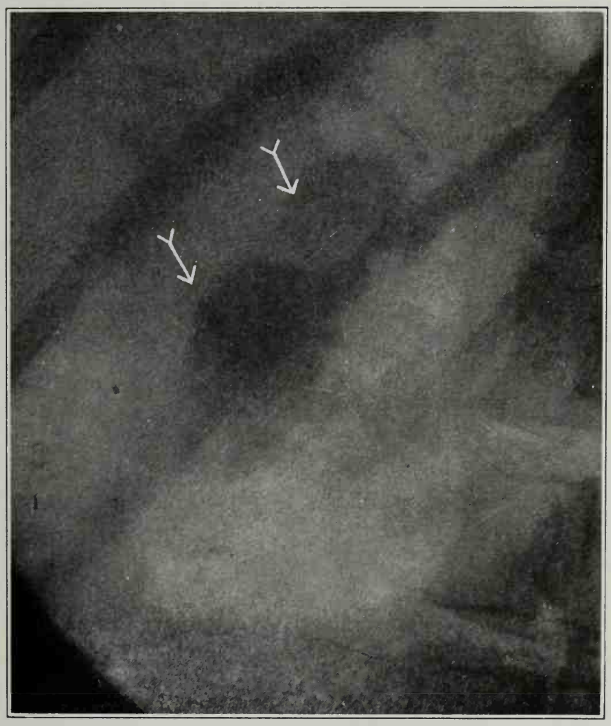

FIG. 1.—Calcified retroperitoneal gland suggesting gall-stones.

masses sometimes occur scattered throughout the spleen and may occur anywhere beneath the peritoneum as the end-result of localized tuberculous processes. An extensive calcification is sometimes encountered in tuberculous kidneys. Extensive sheets of calcification are sometimes seen in the pleura and very rarely in the pericardium following tuberculous or other infections.

The calcification which occurs in arterial walls as a result of arteriosclerosis is a familiar picture. It may be found in the course

of any of the arteries, and is sometimes extensive and striking. The age of the patient must always be taken into consideration in estimating its proper significance. When it occurs in a young patient it is most commonly the result of lues. These changes occurring in the internal iliac arteries may be mistaken for stone in the ureter.

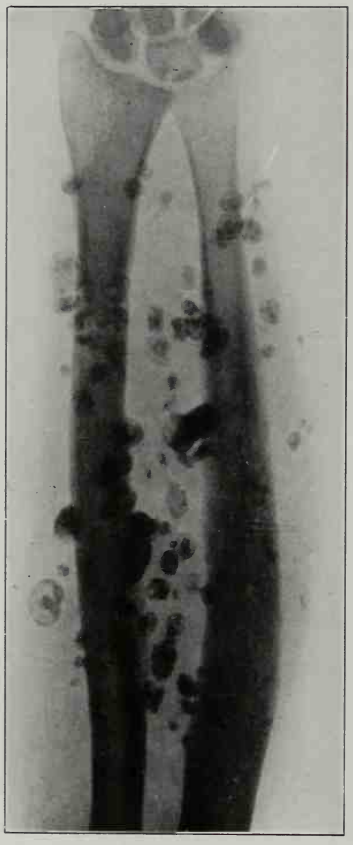

FIG. 2.—Calcification in angioma.

Calcification appears in veins in the form of small, rounded, dense masses, so-called phleboliths, which represent small calcified thrombi on the distal side of the valves. They are most common in the pelvis in the region of the ischial spines where they are frequently mistaken for ureteral stones, and may also occur in the superficial veins, particularly in the leg. Rarely, calcification similar to that seen in arteriosclerosis may be evident in old varicose veins.

Extensive calcification may occur in hematomata; this is most commonly seen about the elbow and in the quadriceps extensor. It may develop rather suddenly several weeks after an injury and present an appearance on the plate which resembles periosteal sarcoma.

Definite irregular deposits of calcium salts may be found about foreign bodies, such as silk sutures, the cysts of parasites, and very rarely within a dead fetus.

Calcification is fairly common in tumor masses whose blood supply has been obliterated, of which an ordinary example is that seen in uterine fibroids. It is encountered also in other slow-growing and benign tumors of the connective-tissue group, such as fibromata and lipomata. It occurs in certain slowly growing scirrhous carcinomata and has been noted in some tumors in the pancreas and gall-bladder as well as in glandular metastases. Angiomata may contain round cyst-like masses of varying size, representing calcified thrombi, and endotheliomata frequently contain irregular dense areas, as, for example, in psammomata in the skull.

Small thin plaques often occur in the dura mater and falx cerebri. Deposits are also seen in the pineal-thyroid, testes, ovaries and other glands; and in the subcutaneous tissues of the shins, dense scar tissue, and along tendons and their attachments as a result of old inflammation.

Mention must also be made of the fact that infarcts of any of the viscera may subsequently calcify. Another rare condition is the so-called calcareous metastasis in which in extreme resorption of bone from extensive caries, malignant disease, etc., a widespread deposit of calcium salts may occur in the cartilages, mucous membranes of the mouth, stomach and arteries.

Concrements.—Solid calcareous masses, usually the result of chronic infection, are found in the nose, tonsils, salivary ducts, appendix, bile passages and genito-urinary tract.

Areas of Increased Density in Spongy Bone.—Small round areas of condensation are sometimes seen in cancellous bone. There is no disturbance in the normal structure of the bone about them, and their significance has been a matter of considerable speculation. They may represent old healed areas of infection or some localized disturbance in the growth of the bone. At any rate, they have no pathological importance. They may occur near the ends of long bones, in the carpus, tarsus or within any of the flat bones. The transverse dense lines, often multiple, which occur along the medul-

lary canal toward the end of the long bones, are the result of disturbances of growth which occurred at the time when the epiphyseal line was at that point; they may be likened to the growth of rings in the trunk of a tree.

FIG. 3.—Intramuscular iodine injection. The shadow of the metallic deposit can be seen scattered over that of the pelvic bones.

Warts and Fibromata on the Skin.—Any area of skin which presses heavily on the plate will be recorded as a spot of increased density, common examples of which are outlines of the buttocks of a thin individual in a plate of the entire pelvis, the breasts of women in anteroposterior plates of the chest or the ears in lateral skull plates. In the same way warts and fibromata appear as rounded areas of increased density, which when they occur in the kidney and gall-

bladder regions may strongly suggest calculi. A characteristic which may help to identify them is that they have extremely sharp margins because of the fact that they are in contact with the plate. The presence of fibromata should always be noted in the patient's record.

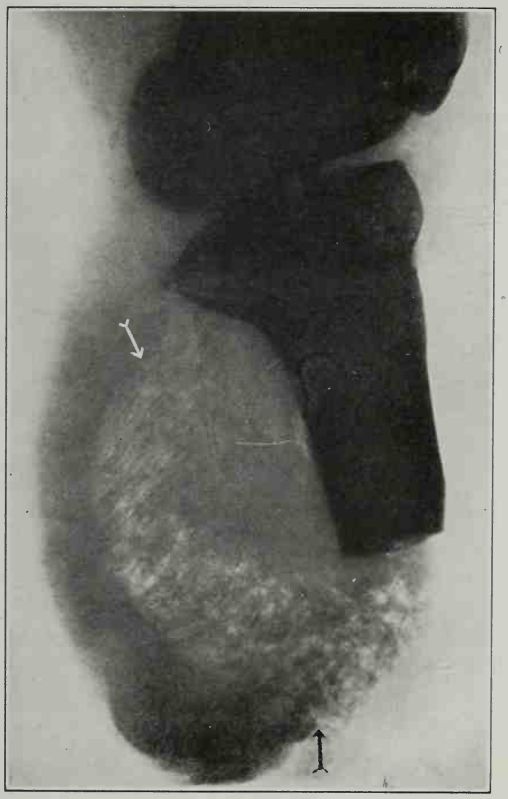

FIG. 4.—Gas gangrene following amputation of the leg. Note the sharply defined bright areas in the soft tissues.

Metallic Salts.—Dense shadows of the metallic salts may be seen where there are bismuth or barium residues in a sinus which has been injected or in portions of the gastro-intestinal tract; where zinc or mercurial ointments are present on the skin, or where iodin which in any form casts a shadow of particular density has been used. The presence of iodin upon the skin, or within the soft tissues as a result of intramuscular injection is quite striking (Fig. 3).

Gas.—Air or gas in the soft tissues also gives a characteristic picture. Accumulations of gas, particularly in the colon where it

overlies the spine, the wings of the ilia or sacrum, are sometimes mistaken for areas of rarefaction in the bone. Careful inspection will reveal the presence of normal bone structure in the doubtful area or the patient may be reëxamined.

Defective Plates.—Plates may show irregular light or dark areas as a result of defects of manufacture, or fogging by light or *x*-rays. One particularly troublesome defect is the occurrence of localized thin spots in the emulsion which give shadows light in color resembling those of stones. Similar defects are produced by localized pressure or pinching of the emulsion and is a frequent occurrence when celluloid film is used instead of the glass plate. Irregular patterns of increased or diminished density occasionally result from uneven immersion of the plate in the developer; these are very sharply marked and have long curved outlines. Fingermarks appear on plates as light or dark spots, depending upon the substance present on the finger at the time of impression; their presence is always an indication of faulty dark-room technic.

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CHAPTER II.

ANATOMICAL VARIATIONS AND DEVELOPMENT.

ANATOMICAL variations in bone structure may occur anywhere in the skeleton and are of considerable importance aside from their interest as curiosities, for they are commonly points of lowered resistance. A strain or injury which would be without effect on a normally constructed individual may give rise to severe and stubborn symptoms when such anomalies are present. This is particularly true of variations in the spine.

Skull.—The skull may show partial absence of bones or variation in the width of sutures, of which extreme examples are acephalic monsters. Thin areas appearing as holes are occasionally seen in the frontal and parietal regions and along the sagittal suture. The sinuses and mastoids are subject to wide variation, from complete absence to enormous size. Cases have been observed in which the mastoids communicated with the sphenoid sinus anteriorly and with each other posteriorly.

Vertebræ.—A most common anomaly in the spinal column is the presence of extra bodies, *e. g.*, six lumbar or thirteen thoracic segments, or of extra portions of bodies which take the form of a triangular wedge which may bear an extra rib when it occurs in the thoracic region (Fig. 5).

Another frequent finding is the failure of union of the posterior ring. All degrees of this condition are seen from bifid spinous processes to complete spina bifida.

There may be increase of length or size of the transverse processes, particularly in the last cervical and last lumbar vertebræ. There are all gradations found up to partial or complete fusion of the process with the sacrum, or so-called sacralization. These enlarged processes give rise to symptoms whenever, on account of size or position, they cause pressure on nerve trunks or impinge on neighboring bones. On the other hand, the processes of the first lumbar are often short and have accessory ribs attached; these may be mistaken for fractures.

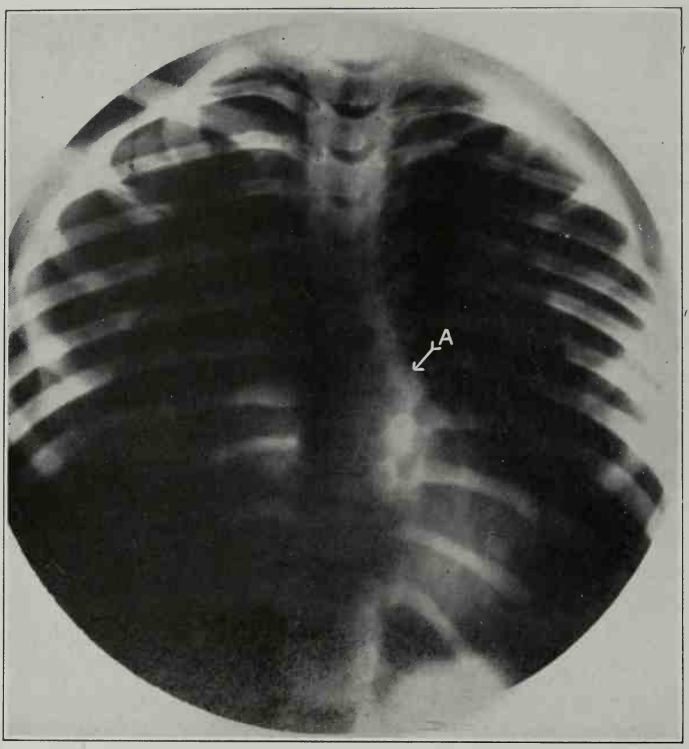

FIG. 5.—Congenital abnormality. Wedge-shaped vertebra at *A*.

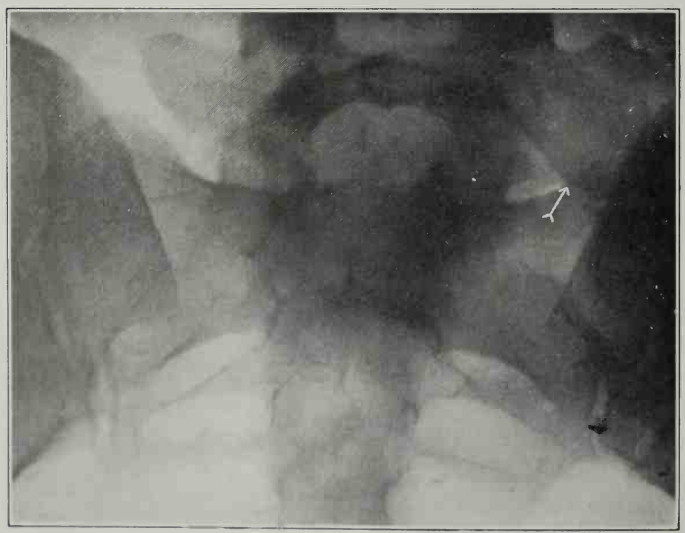

FIG. 6.—Enlarged sacralized transverse process on fifth lumbar vertebra.

While spinous processes are ordinarily arranged in a straight line, slight lateral deviations of individual processes may occur without pathological significance. Unusually long or thick spinous processes may impinge on one another, especially in the lumbar spine in cases of exaggerated lumbar curve.

There is a considerable variation in the plane of the articular facets at the lumbosacral junction. Normally, these articular surfaces are approximately transverse, but one or both may be rotated

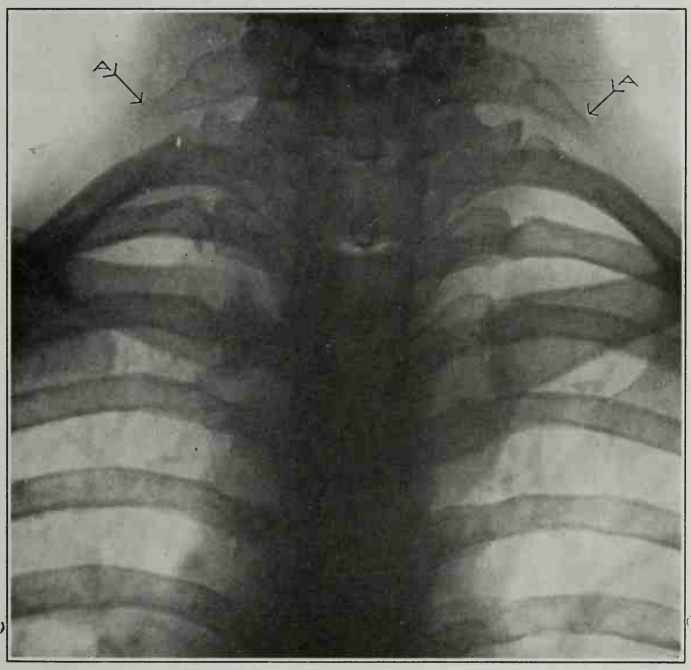

FIG. 7.—Double cervical ribs at *A*.

so that the plane of the articulation between them is anteroposterior. These are a potential source of symptoms in the lower back because they permit of various degrees of forward dislocation of the fifth lumbar vertebra upon the sacrum.

Ribs.—An anomaly which has already been mentioned is the occurrence of extra ribs which may appear in the lower cervical or upper lumbar regions or attached to extra bodies. These cervical ribs may be of sufficient length to articulate with the sternum or be attached to the first rib. They are usually longer than they

appear on the plate, due to foreshortening of their shadow. On the other hand, one or more ribs may be absent, or partially so, or adjacent ribs may be fused. A mild form of this latter condition is frequently seen near the sternal end, where a rib may flare considerably before its attachment to the costal cartilage, and this enlargement may or may not be perforated.

Scapulæ.—These bones vary considerably in thickness and holes may occur in the thin regions, especially in old people; in the same way unusually prominent grooves may simulate fractures. There is a condition known as congenital elevation of the scapula (Sprengel's deformity), in which a partially developed scapula is found high up toward the neck. In cases of obstetrical paralysis there may be an imperfect development of the scapula and head of the humerus.

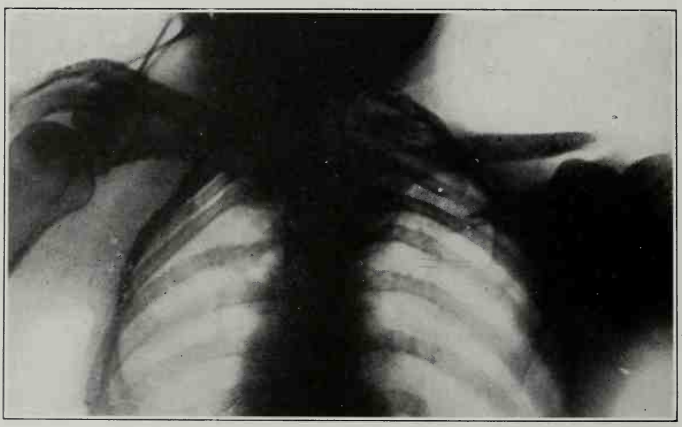

FIG. 8.—Congenital abnormality of the scapulæ.

Variations of the Carpus.—Perhaps the most important anomaly here is the divided scaphoid, which is to be differentiated from a fracture of the scaphoid. The margins of the halves are more rounded and smooth and the space separating them is not quite so black as in the case of fracture. The semilunar and the radial sesamoid of the thumb may be similarly divided. Small extra bones may be found, of which the most common is the styloid; this develops from an extra center of ossification lying between the trapezoid, the magnum and the third metacarpal.

Variations of the Tarsus.—The astragalus bears a backward prolongation of variable length which often exists as a separate bone, the trigonum; when present it must be differentiated from a frac-

ture of a long process. The next in order of importance is the tibiale externum, a small detached bone which sometimes occurs at the posterior end of the scaphoid on the inner side of the foot. The peroneum in the tendon of the peroneus longus overlying the cuboid may be subdivided.

The small separate center of ossification on the outer side of the posterior end of the fifth metatarsal may persist into adult life as a small bone called the vesalianum.

Divided sesamoids in the tendons of the flexor hallucis brevis beneath the head of the first metatarsal are fairly common. They must be carefully differentiated from fracture of single sesamoids, which are extremely rare.

The subject of variations in the hands and feet is exhaustively treated by Dwight.

Other Bony Variations.—In every roentgenological practice one may encounter cases of partial or complete absence of long bones, particularly the fibula, radius and phalanges. On the other hand, supernumerary bones, usually extra fingers or toes, may also be seen. Fusion of bones may be looked for occasionally; this is most frequently found between the radius and the ulna. Adjacent carpal and tarsal bones may be united, and there is a hereditary anomaly in which the first and second phalanges of one or more digits may coalesce with obliteration of the interphalangeal joint. Atavistic variations may occur, as, for example, the hooked supracondylar process occasionally found on the inner margin of the humerus above the elbow.

Ossification.—Variability is also evident in the time of appearance of centers of ossification. The following table gives the appearance time of the centers in the fetus:

TABLE OF APPEARANCE OF CENTERS OF OSSIFICATION.

Head.	
Mandible	7th week
Occipital bone—squamous portion	8th "
lateral and basilar	9th to 10th "
Superior maxilla	8th "
Temporal bone—petrous, mastoid and zygoma	9th "
Sphenoid—inner lamella of pterygoid process	9th "
great wings	10th "
lesser wings	13th "
anterior body	13th to 14th "
Nasal bone	10th "
Frontal bone	9th to 10th "
Bony labyrinth	17th to 20th "
First dentition—rudiments	17th to 28th "
Hyoid bone—greater cornua	29th to 32d "

Shoulder Girdle.	
Clavicle—diaphysis	7th week
Scapula	8th to 9th "
Upper Extremity.	
Humerus—diaphysis	8th week
Radius—diaphysis	8th "
Ulna—diaphysis	8th "
Phalanges—terminal	9th "
basal 2d and 3d	9th "
basal 4th and 1st	10th "
basal 5th	11th to 12th "
middle 3d, 4th, 2d	12th "
middle 5th	13th to 16th "
Metacarpals—2d and 3d	9th "
4th, 5th, 1st	10th to 12th "
Vertebræ.	
Arches—all cervical and upper 1st and 2d dorsal	9th week
all dorsal and 1st or 2d lumbar	10th "
lower lumbar	11th "
upper sacral	12th "
4th sacral	19th to 25th "
Bodies from 2d dorsal to last lumbar	10th "
from lower cervical to upper sacral	11th "
from upper cervical to lower sacral	12th "
5th sacral	13th to 28th "
1st coccygeal	37th to 40th "
structural arrangement	13th to 16th "
odontoid process of axis	17th to 20th "
Costal processes—6th and 7th cervical	21st to 33d "
5th cervical	33d to 36th "
4th, 3d, 2d cervical	37th to 40th "
Transverse processes—cervical and dorsal	21st to 24th "
lumbar	25th to 28th "
Ribs and Sternum.	
Ribs—5th, 6th, 7th	8th to 9th week
2d, 3d, 4th, 8th, 9th, 10th, 11th	9th "
1st	10th "
12th (very irregular)	10th "
Sternum.	
Sternum	21st to 24th week
Pelvic Girdle.	
Ilium	9th week
Ischium—descending ramus	16th to 17th "
Os pubis—horizontal ramus	21st to 28th "
Lower Extremity.	
Femur—diaphysis	8th to 9th week
distal diaphysis	35th to 40th "
Tibia—diaphysis	8th to 9th "
proximal epiphysis	40th "
Fibula	9th "
Os calcis	21st to 29th "
Astragalus	24th to 32d "
Cuboid	40th "
Metatarsal—2d and 3d	9th "
4th, 5th and 1st	10th to 12th "
Phalanges—terminal 1st	9th "
terminal 2d, 3d, 4th	10th to 12th "
terminal 5th	13th to 14th "
nasal 1st, 2d, 3d, 4th, 5th	13th to 14th "
middle 2d	20th to 25th "
middle 3d	21st to 26th "
middle 4th	29th to 32d "
middle 5th	33d to 36th "

The following table from Rotch and Morris can be relied upon as a working average of the time of appearance of ossification centers after birth:

	Time of appearance. Years.	Time of Fusion. Years.
Scapula—coracoid	1	15
upper glenoid and base of coracoid	10	15
acromion (two centers)	15	20
vertebral border	20	25
Ribs—epiphyses for head and tubercle	15	23
Clavicle—small epiphysis of the sternal end	18	25
Humerus—head	1	20
greater tuberosity	3	20
lesser tuberosity	4	20
(all fuse at six years and join the shaft at twenty years.)		
capitellum	1	17
internal epicondyle	5	18
trochlea	10	17
external epicondyle	12	17
(The capitellum, trochlea and external epicondyle join as a mass at seventeen and the internal epicondyle at eighteen years.)		
Radius—head	5	17
lower epiphysis	2	20
Ulna—olecranon	10	17
Lower epiphysis	4	18
Carpus—(in the order of appearance):		
magnum	1	
unciform	1 to $1\frac{1}{2}$	
cuneiform	2 to 3	
semilunar	4 to 5	
trapezium	5	
scaphoid	5 to 6	
trapezoid	6 to 8	
pisiform	12	
Metacarpals—epiphyses	3	20
Phalanges—epiphyses	3	18
Pelvis—(pubis and ischium unite at eight years; the acetabulum closes at sixteen years):		
epiphyses for	0	0
crest of ilium ischial tuberosity anterior inferior iliac spine tubercle of pubes	15	20
Femur—head	1	19
greater trochanter	4	18
lesser trochanter	13	17
lower epiphysis	birth	20
Patella	3	24
Fibula—upper epiphysis	4	24
lower epiphysis	2	20
Tibia—upper epiphysis	birth	22
lower epiphysis	2	18
Tarsus—(in order of appearance):		
calcis	birth	
epiphysis of calcis	10	
astragalus	birth	
cuboid	birth	
external cuneiform	1	
internal cuneiform	3	
middle cuneiform	3	
scaphoid	4	

	Time of appearance. Years.	Time of Fusion. Years.
Metastarsals—epiphyses	3 to 8	20
Phalanges—epiphyses	4 to 7	18
Sesamoids of flexor hallucis brevis	5	

Vertebræ—Ossification is from three primary centers, one for the body and one for each lateral mass. The nucleus for the body is often bilobed, with a partial plane of cleavage in the vertical or horizontal diameter. The laminæ unite during the first year. Five secondary centers described in the anatomies—namely, thin plates on the upper and lower surfaces of the body and the tips of the mammillary tubercle, transverse and spinous processes—appear at the age of fifteen to twenty years and unite at twenty-five. The fifth lumbar vertebra is an exception in that it ossifies from five centers, one for the body, one on each side from which is developed the superior articular process, pedicle and transverse process, and one on each side which subsequently form the inferior articular process, lamina and spinous process.

It is well to bear in mind that epiphyses which appear last are the first to unite and that the nutrient foramen is directed toward them; that ossification begins earliest in the epiphyses bearing the largest relative proportion to the shaft (except the fibula); that when an epiphysis ossifies from several centers, they fuse together before uniting with the shaft.

Thomas Morgan Rotch has called attention to the fact that the time of appearance of the carpal centers is the best index we have of the actual development of an individual.

Delayed Union or Failure of Union.—Variations in the normal process of the union of epiphyses are of great importance as a factor in the production of deformities. For example, failure of development of a center in the lateral masses of the fifth lumbar may result in scoliosis. Abnormal fusing of the lower epiphysis of the radius produces the malformation known as Madelung's deformity, in which the plane of the radiocarpal articulation is rotated inward and backward.

Delayed union may be an evidence of retarded mental or physical development, of which a common example is cretinism; of infections, prominent among which is lues; or of injury.

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CHAPTER III.

FRACTURES AND DISLOCATIONS.

FRACTURES.

It is most important for a roentgenologist to have a thorough knowledge of roentgen anatomy and of the surgical pathology of wound and fracture repair. Gross fractures are, of course, obvious, but in a doubtful case the diagnosis may depend entirely upon the breadth of his anatomical and surgical experience. He should at least know that the more accurately a fracture is reduced the sooner will function be restored and the smaller the callus which results; that calcification begins in callus in from one to four weeks and is usually complete in six; that at first callus may show very little evidence of lime deposit when there is no displacement of fragments; and that an extensive comminution or a malposition of fragments should be accompanied by a large, thoroughly calcified callus.

The prognosis of fractures involving joints should always be guarded because of the fact that there is no means of estimating from the roentgen examination how much damage has occurred to the soft tissues or what effect their repair will have on function. The possibility of organization and calcification in extensive hematomata which may follow injuries to the supporting structures should always be remembered.

The question of union is often a difficult matter to decide from roentgen evidence alone. One cannot determine from a plate showing a fracture without evidence of bony union whether there are soft tissues between the fragments which will interfere with repair, whether an uncalcified callus is present or whether or not there is firm fibrous union. It must not be forgotten that non-union is prone to occur when the site of fracture involves a nutrient artery or when the patient is syphilitic or asthenic.

In the reduction of fractures normal weight-bearing lines should be restored as far as possible and every attempt should be made to replace articular surfaces in their normal planes with reference to

the shaft. In doubtful cases comparison plates of a symmetrical part may help to decide whether a reduction is satisfactory

Fracture lines will usually become obliterated in from three to six months, and if reposition of the fragments has been accurate all evidence of the injury may have disappeared in that time. The shadow of linear fractures in the skull, however, may persist for a longer period, but ordinarily are not visible beyond one year after

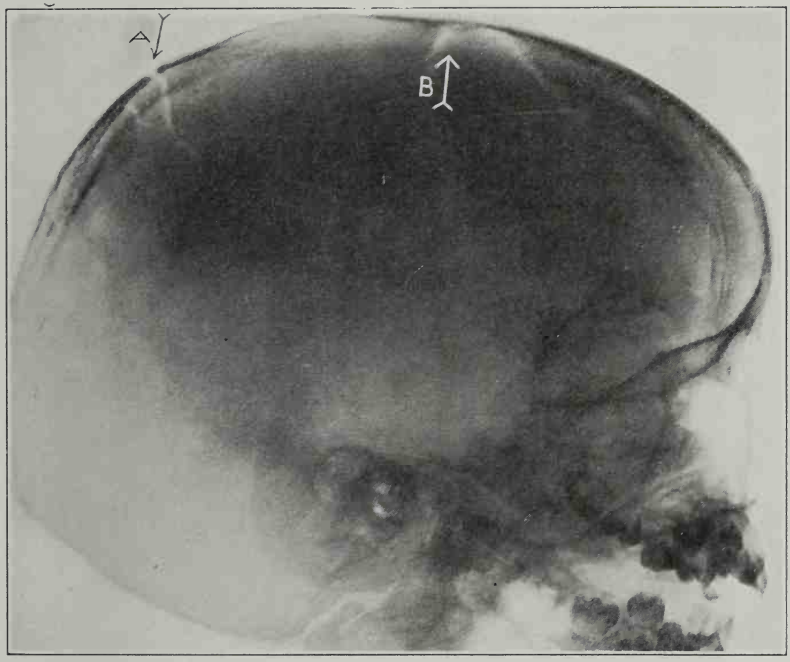


FIG. 9.—Fracture of the skull in a child. Compare the fracture line with the suture line seen above it. *A*, fracture; *B*, suture.

the injury. In any fracture, when reduction has been poor or the callus formation extensive, evidence of the deformity may persist for life.

The roentgenogram will often furnish evidence of value to the surgeon aside from the position of the fragments, such as indications of a pathological process in the bone or of the presence of foreign bodies within the wound, and occasionally the early appearance of gas in the soft tissues as a result of infection with Welch's bacillus.

Skull.—From its structure the skull is subject to linear fractures which appear on the plate as thin black lines with sharp ragged edges. They may run in any direction. They are to be differentiated from suture lines, diploic vessels and arterial grooves, all of which have fairly definite courses, smooth margins and are lighter in color. Fracture lines may open up sutures or follow bloodvessel markings, but they can usually be traced beyond the course of these normal lines.

Fig. 10.—Fracture of the base of the skull. The line of fracture is seen in the petrous portion of the temporal bone.

Comminuted and stellate fractures are usually obvious. A depressed fracture often appears as a white line because of overlapping of the margins of the break; whenever possible profile views should be obtained.

Fractures of either the inner or the outer table appear as areas of slight irregularity in the density and structure of the bone. Fractures limited to the base are frequently overlooked; a vertical projection of the base in addition to an anteroposterior, postero-

anterior and both lateral views should be a routine in searching for skull fractures.

Cranial aerocele may develop following fracture through the sinuses, especially the frontal sinus. They are produced by the increased air pressure within the nasal cavity when the patient sneezes or blows the nose. At this time air and bacteria may be forced through the fracture into the cranial cavity. The pocket containing the air will appear on the plate as an area of markedly diminished density, usually in the frontal region. Plates should be taken from both sides, as it may be absent in one.

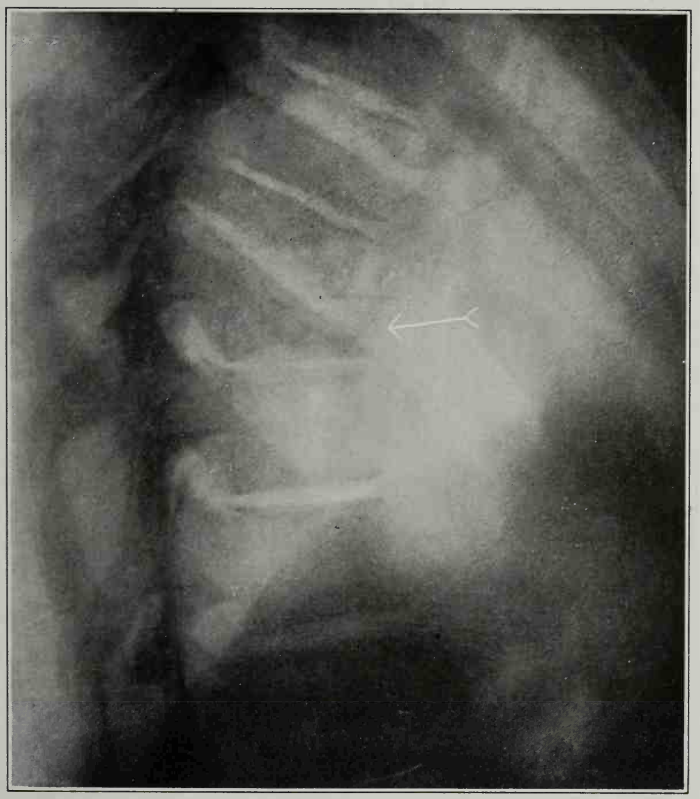


FIG. 11.—Fracture of the spine (lateral view). The injured vertebra is deformed, presenting the characteristic wedge shape.

Vertebræ.—Fracture lines are rarely seen in the bodies of vertebræ. What is seen is abnormality in outline or in relation to neighboring vertebræ. Crushing fractures of the bodies occur most

commonly in the thoracic and lumbar regions as the result of severe injury. They may be overlooked in an anteroposterior view, and a lateral view should always be obtained as a check. These fractures run a long clinical course and give no evidence of callus formation even after months or years. Localized hypertrophic spurs or bridges to adjoining bodies often develop after these injuries.

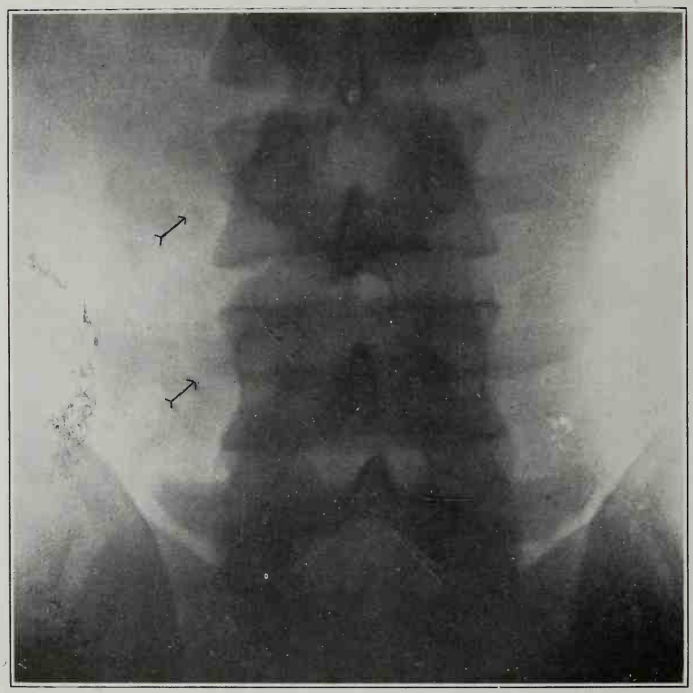


FIG. 12.—Fracture of transverse process of the third and fourth lumbar vertebræ on the right.

Fracture of the body of the fifth lumbar may occur but it is not common. This vertebra, owing to its tilted position, is so distorted in the average picture that its outlines are recognized with difficulty. A diagnosis of fracture of this body should not be made without a good stereoscopic inspection of its direct anteroposterior diameter in addition to a lateral view if possible.

Transverse processes may be fractured by severe lumbar injuries, usually several vertebræ being affected. There may or may not be considerable separation of the fragments.

Fracture of the posterior ring and transverse processes is seldom

directly shown. They may be diagnosed by the change in the relations of the vertebræ at the site of the lesion, usually a slight rotation or angulation so that the spinous processes of the vertebræ above the lesion are out of line with those of the one below. This condition is to be differentiated from the slight lateral deviations which frequently occur in individual spinous processes without significance.

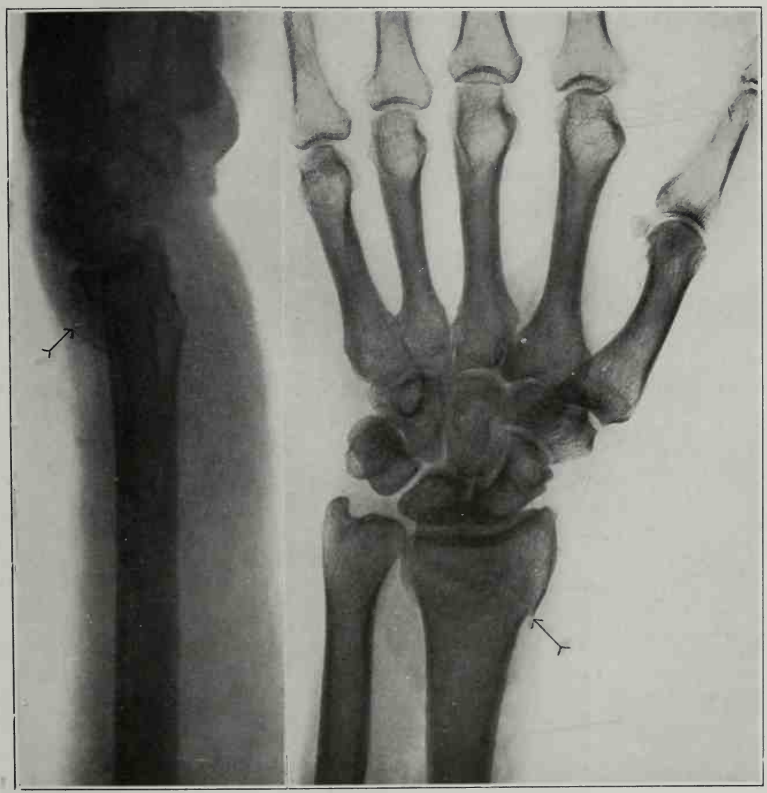


FIG. 13.—Typical Colles's fracture. The lateral view shows the usual deformity (←) compression of the posterior margin of the radius resulting in backward tilting of the articular surface.

Fractures of spinous processes may be suspected from deformities of their outlines in anteroposterior views. A lateral view, however, will usually confirm the diagnosis.

Pelvis.—Pelvic fractures are usually due to violent injuries such as falls and crushes and the resulting deformity is easily recognized.

FIG. 14.—Colles's fracture—lateral view. The shadow of the ulna overlaps that of the radius and conceals the deformity in the radius.

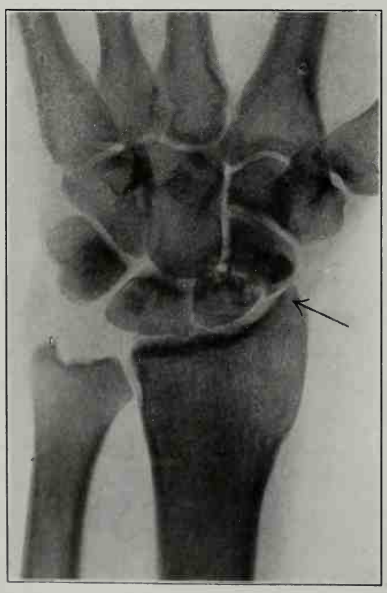


FIG. 15.—Fracture of the scaphoid.

The regions about the sacro-iliac and the symphysis are most frequently involved. A typical injury consists of fracture of the pubis with more or less wide separation of the sacro-iliac, or fracture through the sacrum or ilium close to the synchondrosis. The femoral head may be driven into the pelvis, carrying the inner wall of the acetabulum before it.

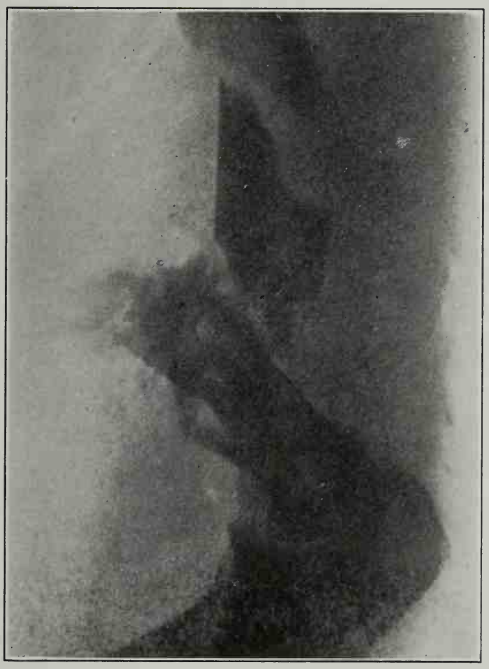
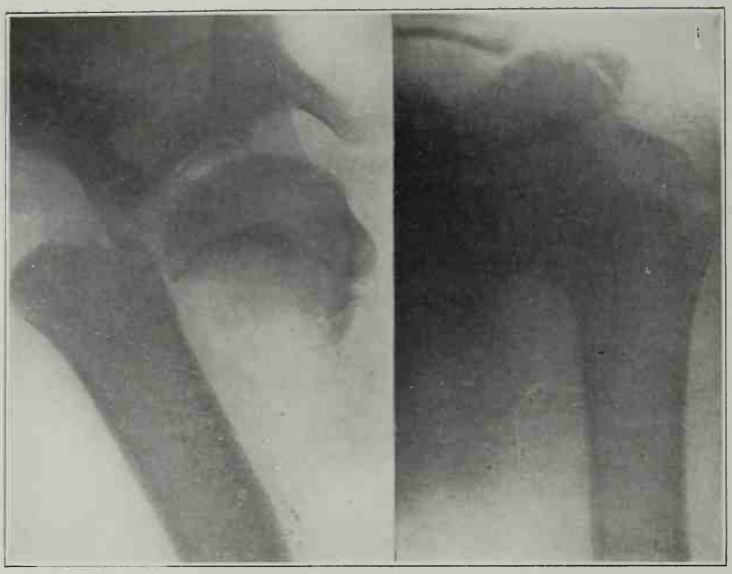


FIG. 16.—Shell wound. Comminuted fracture of humerus. Shot fired from German submarine off Cape Cod, July 21, 1918. The first person to be injured on American territory.

Ribs.—Fractures of the ribs are usually obvious but may be overlooked in the overlapping axillary shadows. Slight rotation of the patient will bring the suspected area into clear view. Fracture of the costal cartilage may occur which, of course, is not evident on the roentgenogram unless the cartilage is calcified. Cartilages which are partially calcified show breaks running obliquely or irregularly through them where calcification has not occurred. These should not be mistaken for fractures.

Carpus.—The bones usually involved in the order of frequency are the scaphoid, cuneiform and magnum. These fractures are often associated with those of the radius and ulna and should not be over-



Vertical projection. Anteroposterior view.

FIG. 17.—Fracture of the anatomical neck of the humerus along the epiphyseal line. The amount of deformity is not well shown in the anteroposterior view.

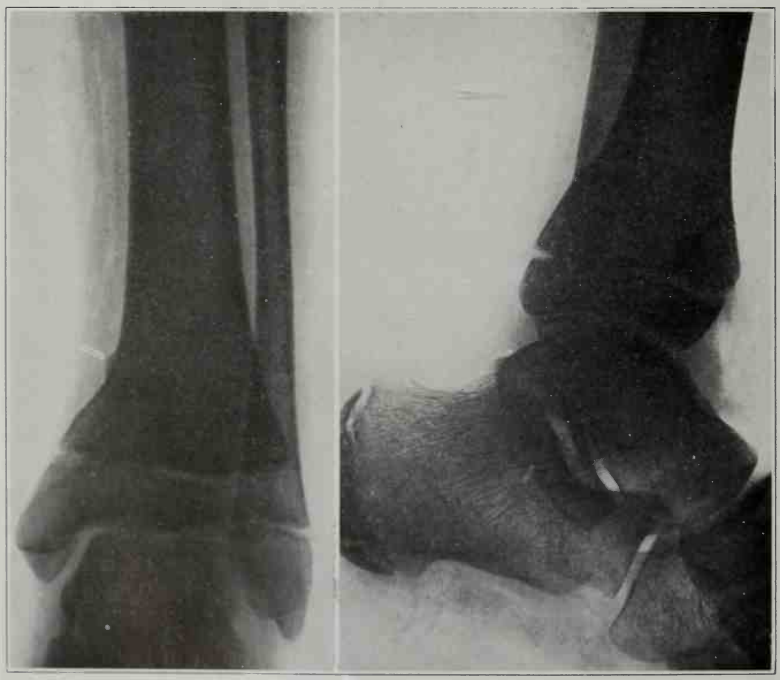


FIG. 18.—Subperiosteal fracture of the tibia. The line of fracture is not visible, but there is a definite break in outline.

looked by exclusive attention to the latter. In case of doubt it is advisable to secure plates of both wrists in symmetrical position for comparison.

Colles's Fracture.—This is probably the most common of all fractures. The usual deformity is a compression of the posterior margin of the radius which results in a backward tilting of the articular

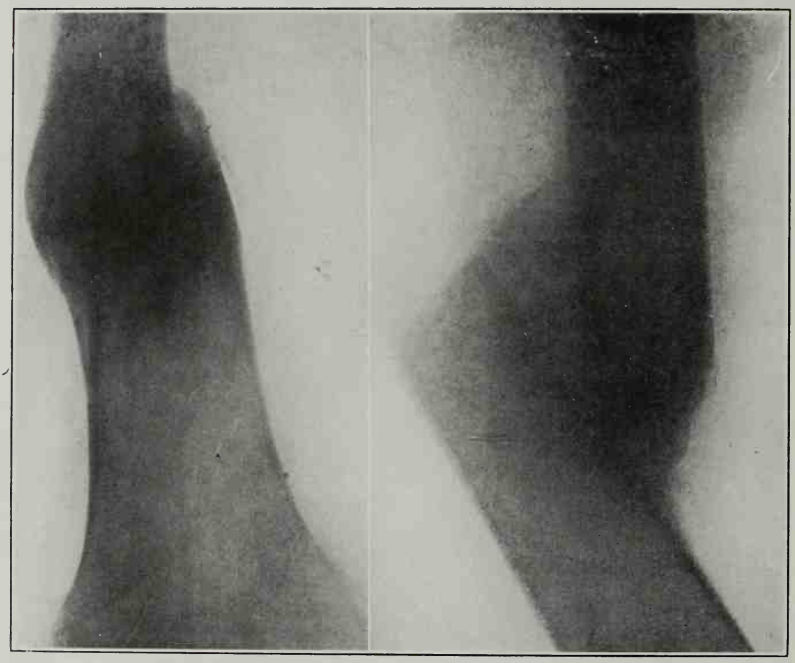
Lateral view. Anteroposterior view.

FIG. 19.—Fracture into the knee-joint; also fracture of the patellæ, showing the importance of taking plates in more than one plane. The fractures are not visible in the lateral view.

surface as seen in the lateral position. After reduction, the former relation of the styloid processes of radius and ulna should be restored and the plane of the articular surface should be tilted toward the palmar surface forming a normal angle with the axis of the shaft. A special type of this injury results from backfiring of automobiles and consists of an oblique fracture through the styloid of the radius.

Elbow.—Fractures here in the order of frequency are supracondylar fractures of the humerus, fractures of olecranon, head of radius and coronoid process. The two latter injuries may occur without a great deal of displacement and may be overlooked unless they are carefully searched for.

Shoulder.—Fractures of the anatomical and surgical neck are usually the result of falls and they may or may not be impacted. Stereoscopic observation of this region or a vertical view is always



Anteroposterior view. Lateral view.

FIG. 20.—Old fracture of the femur, with extensive callus and deformity. The amount of the deformity is seen in the lateral view.

recommended for the recognition of the true relation of the fragments.

Fractures of the scapula are often overlooked on flat plates. Stereoscopic examination will minimize this error.

Tarsus.—Fractures of the os calcis are the most frequent. They produce more or less disturbance in the normal structure consequent upon crushing of the spongy bone and deformity of outline. The line of fracture is seldom seen. The resulting disability is usually

severe. More rarely fractures of the astragalus and cuboid may occur.

Pott's Fracture.—In any fracture of the tibia it is essential that the fibula be explored throughout its extent in order to avoid missing breaks which occur at a different level from that of the tibial injury. The essentials in reduction of a Pott's fracture are that the weight-bearing line be restored accurately and that the foot be slightly inverted.

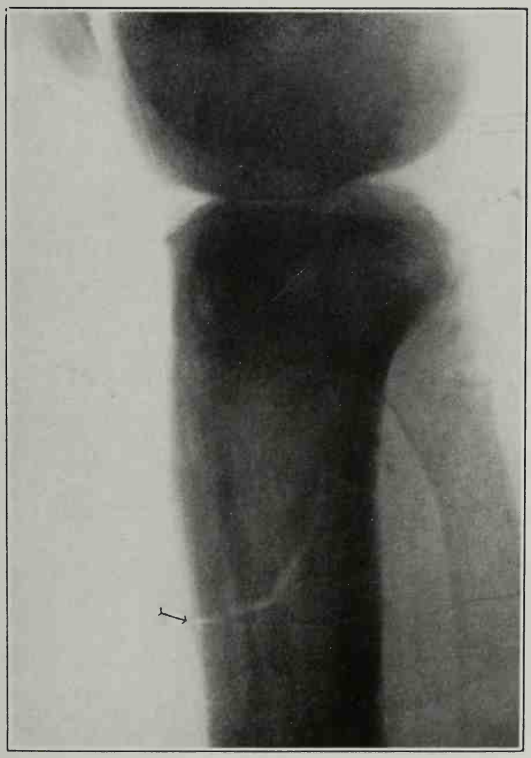


FIG. 21.—Pathological fracture of the upper end of the tibia in Paget's disease.

Knee.—Fractures of the condyles of femur and tibia have the characteristics of fracture involving any joint. The spine of the tibia may be evulsed; the patella may sustain a transverse break with wide separation of the fragments or it may suffer a stellate fracture or shelving fractures of the upper or lower margins as a result of division of the attachment of the patellar tendon.

Hip.—These fractures occur anywhere in the neck of the femur between the head and intertrochanteric line. When there is any dis-

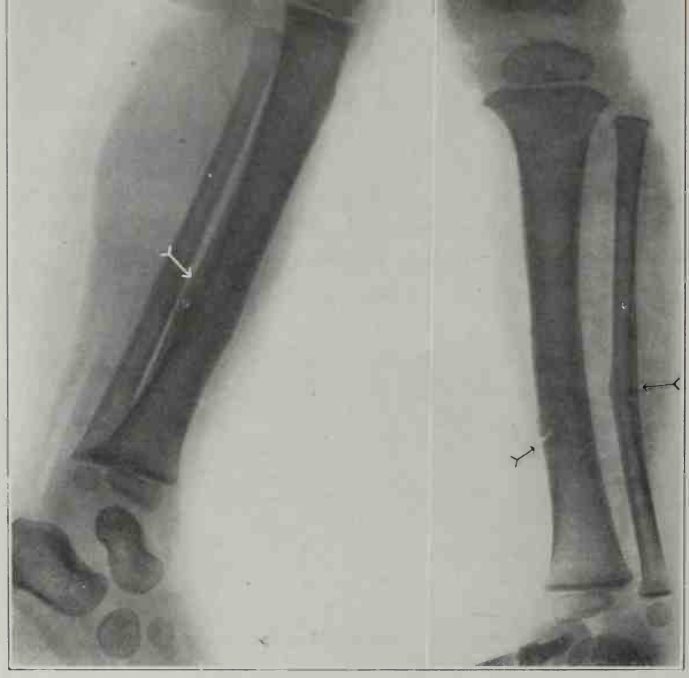


FIG. 22.—Green-stick fracture of the tibia and fibula, with considerable callus formation suggesting periosteal changes.

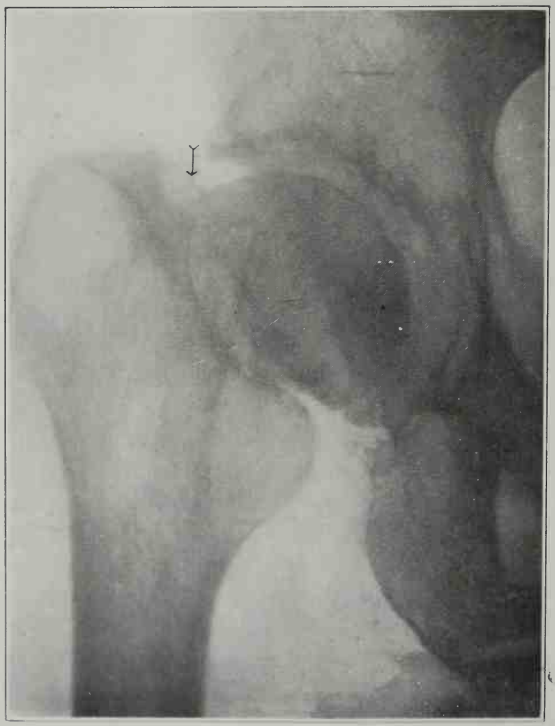


FIG. 23.—Old fracture of the neck of the femur. Note the absorption of the neck, and the absence of callus formation.

placement of the fragments, there will be a disturbance of Shenton's line, which is a smooth, regular curve formed by the upper margin of the obturator foramen, the inferior border of the neck of the femur and the inner margin of the shaft.

In the prognosis of hip fractures the possibility of failure of union and of absorption of the head of the femur must always be kept in mind.

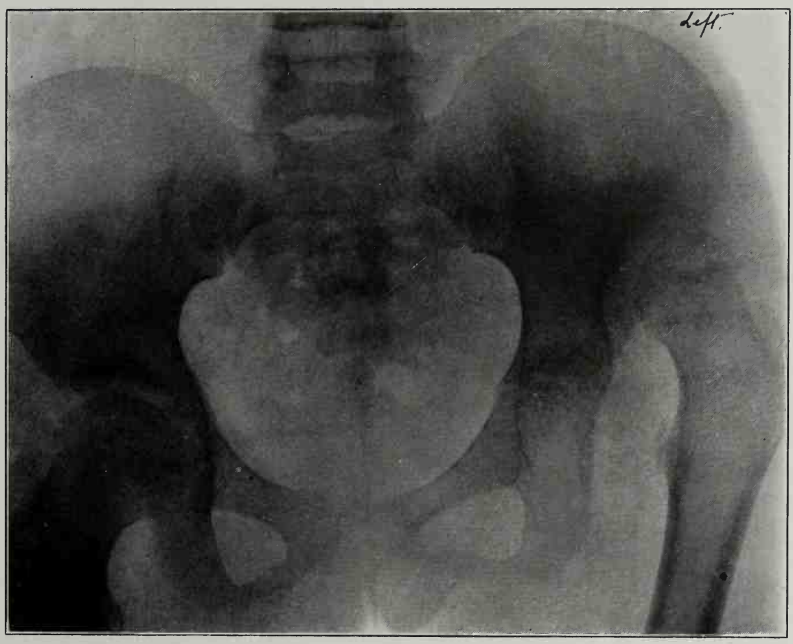


FIG. 24.—Congenital dislocation of left hip.

DISLOCATIONS.

Dislocations of the spine are usually accompanied by fracture. They are most common in the cervical region. The first cervical vertebra may be displaced upon the second with fracture of the odontoid or, more rarely, rotated upon the second without fracture of the odontoid. The most frequent injury is a forward displacement of the upper cervical vertebræ upon the ones below in the region of the third to the seventh.

The sacro-iliac joint may be disarticulated as a result of severe trauma. The so-called sacro-iliac slip is not demonstrated on plates.

Subcoracoid dislocations of the shoulder usually have an asso-

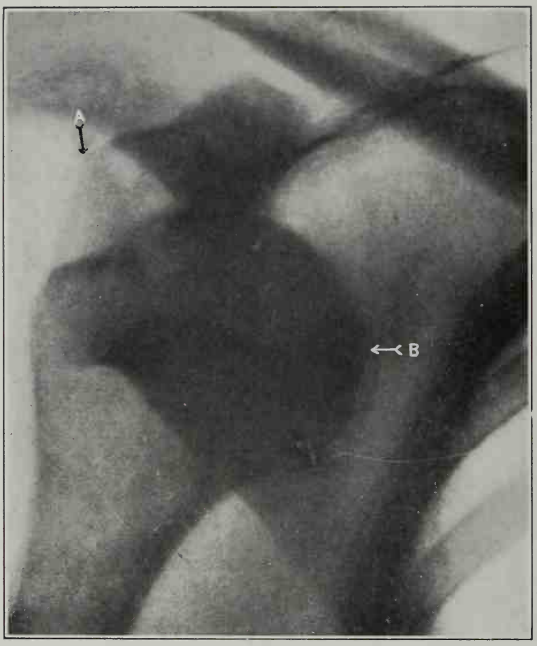


FIG. 25.—Dislocation of the shoulder-joint. *A*, glenoid cavity; *B*, articular surface of the head of the humerus.

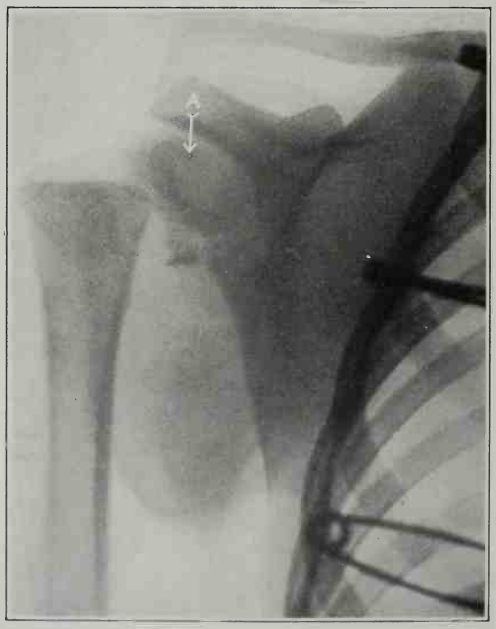


FIG. 26.—Displacement of the epiphysis of the humerus. *A*, head of humerus.

ciated fracture of the greater tuberosity, which is reduced when the head of the humerus is replaced.

In the carpus, dislocations may be suspected when the antero-posterior view shows a loss of the normal, clear zone of articular cartilage about an individual bone because of the fact that it overlaps one or more of the neighboring bones. The semilunar is the one most commonly affected. The condition is readily demonstrated by a lateral view.

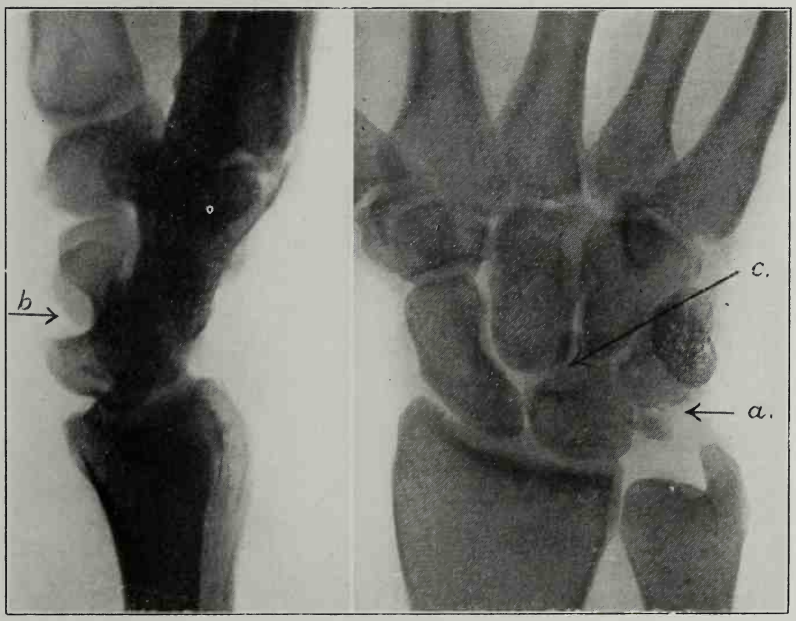


FIG. 27.—Dislocation of semilunar and fracture of cuneiform. Note the concave distal surface of the semilunar at *b*, the disturbed relations of the articular surfaces at *c*, and fracture at *a*.

Epiphyseal separations usually involve a fragment of the adjoining shaft. When unaccompanied by a fracture of the shaft they can only be diagnosed by the abnormal relations of the epiphyses, which do not often occur. Plates of symmetrical parts should always be taken to check up these findings. When these separations are promptly and accurately replaced there is rarely any interference with the growth of the bone.

Delayed union of the ossification center of the tibial tubercle is fairly common, particularly in the presence of a chronic infection such as lues. Separation of the tibial tubercle (Osgood-Schlatter

disease) occurs usually as a result of indirect violence. The tubercle is elevated from the diaphysis and the margins of the epiphyseal line beneath it are thickened and ragged. The soft tissues overlying it are usually swollen and increased in density. A similar injury may occur to the epiphysis of the os calcis.

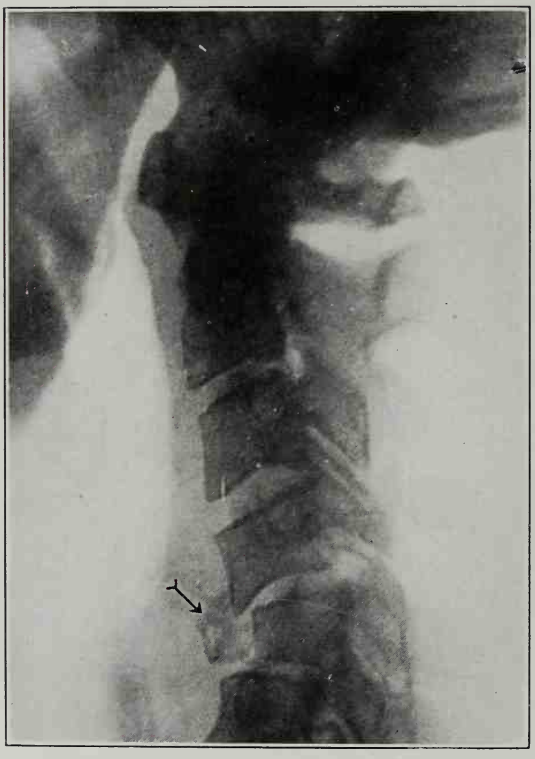


FIG. 28.—Fracture of the fifth cervical vertebræ with backward dislocation.

Congenital dislocations of the hip may be single or double. They are characterized by displacement of the head of the femur upward on the ilium, flattening and deformity of the head, and shallowness of the acetabulum.

Dislocations may occur at any joint. They are usually obvious and require no particular description. In any dislocation careful search should be made after reduction, as well as before, for fractures which may have been overlooked.

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CHAPTER IV.

BONE PATHOLOGY.

Normal bones are smooth and regular in outline, the cortex is homogeneous and the cancellous tissue of uniform consistency. The thickness of the cortex and the texture of the spongy bone vary considerably with the individual The cortex is thickest along the center of the shaft of the long bones, diminishing toward the ends to a thin line which continues beneath the articular cartilage. The student should have a general idea of the normal thickness of the cortex of each individual bone.

Bone disease is manifested by changes in size, in outline and in density. Various forms and combinations of these changes result from the action of pathological agents, so that it is often difficult from the roentgen findings alone to identify positively the causative factor. For this reason the clinical history should always be combined with the roentgen findings in making a diagnosis.

Bones are increased in size in osteomyelitis, tumors, Paget's disease, syphilis and cystic disease. They are diminished in size as a result of trophic disturbances, paralysis, chronic disease of neighboring joints or in developmental anomalies. Changes in outline result from periostitis, which may be traumatic or infectious, from callus formation and from tumors of the bone.

Changes in density may be either local or diffuse. Diminished density (increased radiability) occurs as a result of disuse, infection or of actual destruction from involvement by tumor, cyst or surgical intervention. Increased density occurs as a diffuse process in old osteomyelitis, in syphilis and in Paget's disease. It is found locally about certain low-grade infections and carcinomatous metastases of slow development.

In the presence of a pathological process in bone, the following points should be determined: (1) Is there involvement of the medulla; (2) is there evidence of involvement of the cortex; (3) is there any associated pathology in the soft parts; (4) is the lesion multiple; (5) is it confined to the shaft or does it invade the epiphysis and joint; (6) are neighboring bones affected; (7) is it destructive or proliferative or both?

Osteomyelitis.—The characteristics of this process are a variable amount of destruction of medulla and cortex; extensive reaction of the periosteum whenever involved; sequestration and irregular sclerosis. It may attack any bone at any age and rarely extends beyond the epiphyseal line.

FIG. 29.—Osteomyelitis of the upper end of the tibia of a child.

The process may exist one or two weeks without producing any changes whatever in the shadow of the affected bone. Then areas of diminished density appear at the site of involvement. Proliferation of the periosteum occurs as a result of irritation beneath it and may become extensive, as more of the bone is involved leading ultimately to the formation of a shell of new bone, the involucrum, about the necrotic mass of the old shaft which then becomes a

sequestrum. The process may involve only a portion of the shaft, in which case a variable amount of irregular sclerosis appears about the affected area and a small sequestrum may form.

Two atypical forms are the virulent or fulminating type and the non-virulent bone abscess. The former may give very little positive roentgen evidence or show extensive irregular rarefaction throughout the bone with elevation and thickening of the periosteum, but

FIG. 30.—Osteomyelitis of the second metacarpal.

no sclerosis, or new bone formation. The avirulent type shows a circumscribed area of rarefaction in the medulla usually with a wall of increased density about it and little or no proliferation of the overlying periosteum.

Tuberculosis.—This disease appears in the bones as a slowly progressive, local, destructive process without attempt at regeneration. It most commonly attacks the joints or epiphyses in young individuals and is rarely found in the shaft. The early stages may

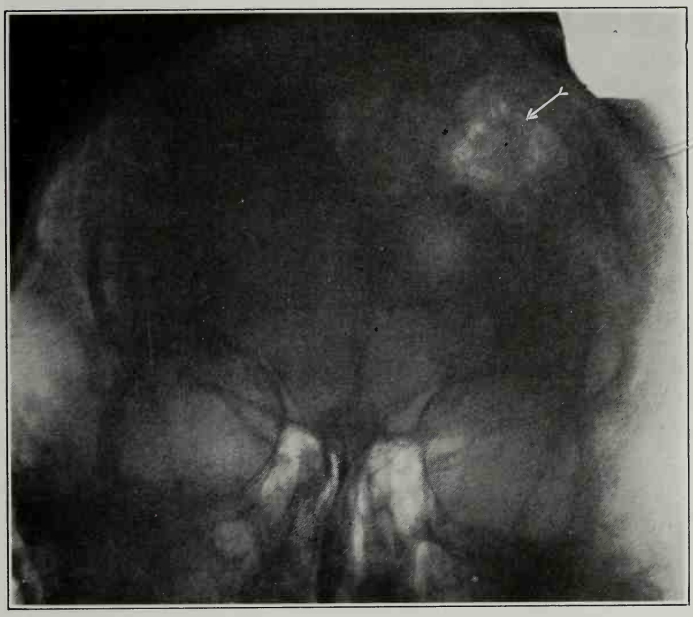

FIG. 31.—Necrosis of the skull.

FIG. 32.—Osteomyelitis of the ilium in a child. The increased radiability shown here as a result of bone destruction must not be confused with a somewhat similar appearance due to gas in the colon.

show merely effusion in the affected joint, but rarefaction of the neighboring bones soon occurs resulting in the characteristic blurred, hazy picture with loss of detail and perhaps local areas of destruction in the affected epiphyses. In the carpus and tarsus this bone atrophy may be severe so that the bones appear of the density of soft parts with finely penciled outlines. Enlargement and squaring of the epiphyses is the rule. As the process continues there is more

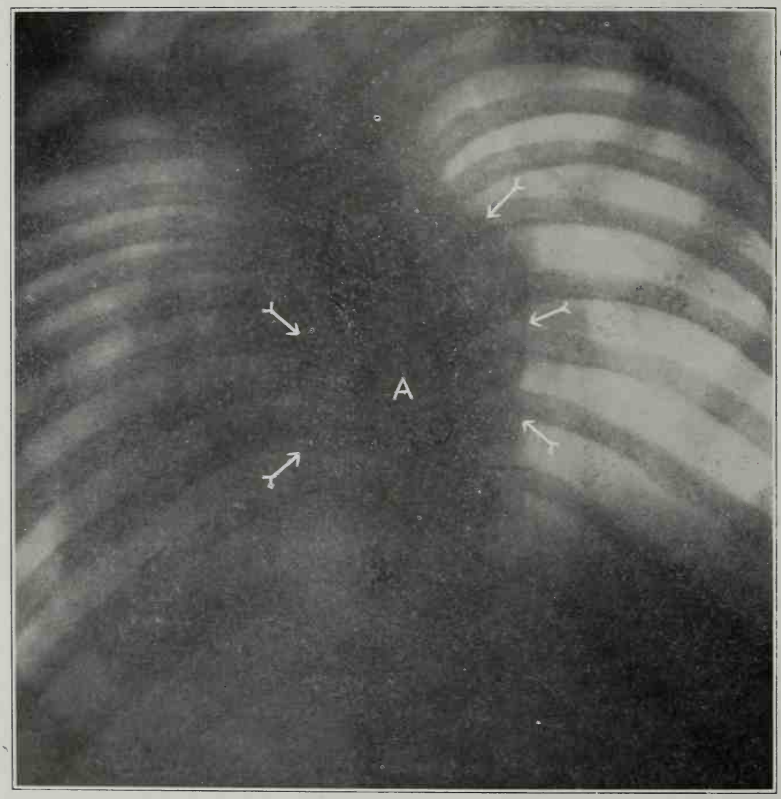

FIG. 33.—Tuberculous spine (anteroposterior view). Diseased vertebræ at "*A*." Arrows indicate margins of a prevertebral abscess.

or less destruction of the joint surfaces eventually resulting in ankylosis as the process heals. Periostitis may develop in the neighborhood of tuberculous lesions, and cause them to be mistaken for syphilis.

The rare cases of tuberculosis of the shaft appear as an irregular destruction in the medulla resembling that seen in a syphilitic osteomyelitis but without involvement of cortex or periosteum.

In the spine tuberculosis usually begins in the neighborhood of the intervertebral discs and destroys the adjacent body or bodies, which collapse, producing a kyphos. This portion of the spine is often surrounded by the fusiform shadow of a prevertebral abscess. Calcification may occur later in such an abscess.

FIG. 34.—Tuberculous spine. Diseased vertebræ at "*A*" (lateral view).

Caries sicca is a slow destructive process which is most common in the shoulders. It causes irregular erosion of the joint surfaces and the epiphyseal end of the humerus. There is no decalcification; on the contrary, there may be slight increase in density in the affected area.

Dactylitis (spina ventosa) is characterized by considerable increase in the diameter of the diseased phalanx, which shows extensive areas of destruction in the medulla. The cortex may be somewhat thin or slightly increased in thickness. This condition is differentiated from syphilitic dactylitis by the fact that the enlargement in the latter is due to periosteal proliferation with the formation of a collar of new bone outside of the old cortex and comparatively little involvement of the medulla. However, differentiation of the two conditions is at times extremely difficult from the roentgenogram alone.

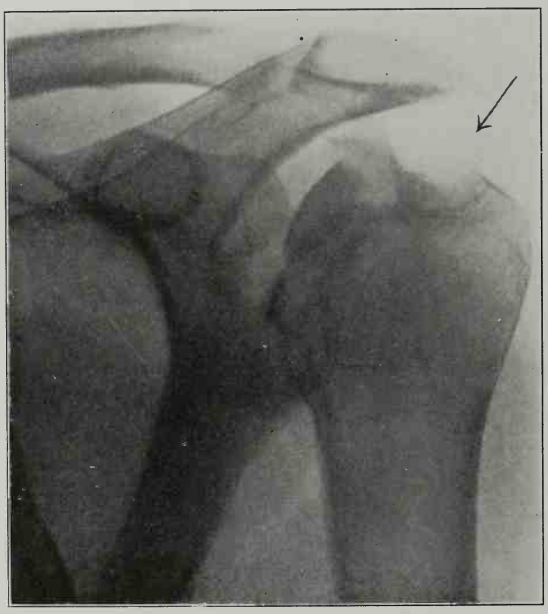

FIG. 35.—Caries sicca. Note the destruction of head of humerus.

Syphilis.—Syphilis is a destructive and proliferative process, assuming varied forms which may simulate other conditions. It attacks any bone at any age. Its commonest manifestations are periostitis and irregular areas of destruction.

Periostitis is usually limited to the shaft, and the picture which results from it varies according to the age and activity of the process. When acute the appearance is that of multiple distinct, thin laminæ laid down upon the old cortex, and the outline of the free margin is usually irregular. As the condition becomes more

chronic these laminæ become thicker and more compact, so that ultimately the area involved becomes as dense as the normal cortex. At the same time the surface loses its fringy character and becomes smooth, although it may be more or less irregular. This increase in thickness of the cortex will often give an appearance of bowing, as is seen in the so-called saber tibia, for example. It should be noted that this thickening of the cortex usually occurs on the convex

FIG. 36.—Congenital syphilis (periosteal type).

side of the curve as compared with rickets, where it appears on the concave side. There is often an endosteal proliferation with narrowing of the medullary canal due to encroachment by the thickened cortex.

Periostitis may also occur as small local elevations of the periosteum (bone blisters) near the ends of the long bones or may assume the form of multiple confluent small blisters. There is another type of lesion, a sort of lacework pattern, which consists of strands of

calcified material which run out at right angles to the cortex and arch together at their terminations. Running through this pattern, parallel to the shaft and midway between the cortex and the periphery, there is a definite thin sheet of calcification. At the margins of the process where it blends into the normal bone is the usual type of laminated periosteal thickening. This type of periostitis is sometimes mistaken for periosteal sarcoma. In the congenital

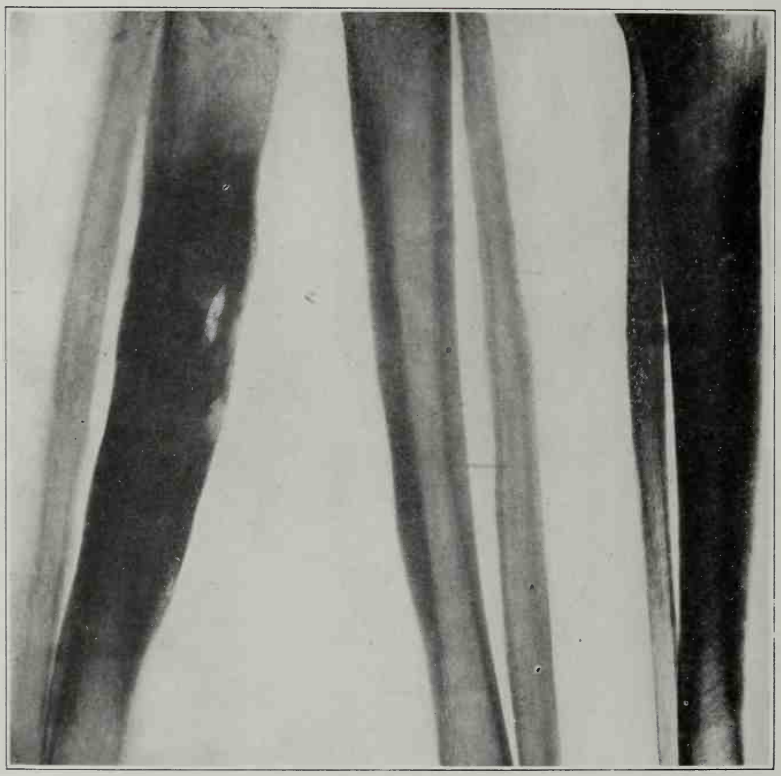

FIG. 37.—Types of syphilitic periostitis of the tibiæ.

form in infants the periosteum may be floated away from the shaft for a considerable distance, leaving a clear space between it and the cortex. More or less sharply circumscribed "punched out" areas of increased radiability may be found in the new periosteal bone.

Irregular areas of destruction may occur in any bone, usually as a result of gummatous changes. In the skull the picture is striking and represents punched-out areas involving both the outer and inner

table. In the long bones they are usually associated with periosteal changes, although at times a bone may be riddled with these areas of rarefaction and show only slight periosteal change. This is particularly common in the more acute cases. In children a common

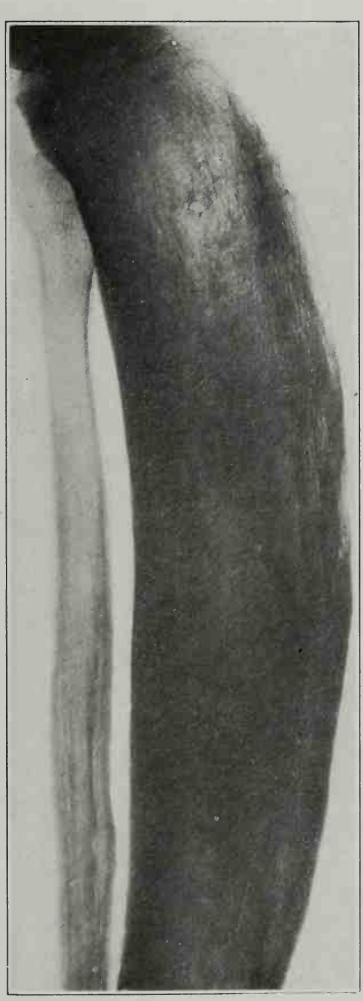

FIG. 38.—Syphilitic periostitis (congenital type).

picture is the so-called juxta-epiphyseal lesion, which occurs in the diaphysis near the epiphyseal line. It is characterized at first by an irregular loss of substance close to the epiphyseal line and perhaps a slight periostitis. The affected area later becomes sclerosed, lead-

ing to the formation of a white line at the epiphysis which resembles somewhat that seen in scorbutus.

Joint lesions may be unilateral or symmetrical. Ordinarily little is seen beyond an increase in density in the soft parts, due to effusion and synovial thickening. Later on, low rounded hypertrophic growths may appear about the margins of these joints. Extensive destructive processes may sometimes occur in the epiphyseal ends of bones, causing considerable deformity. Localized areas of destruction suggesting tuberculosis may sometimes be found in the epiphyses of children.

FIG. 39.—Syphilitic dactylitis.

In the spine, lues causes the destruction of one or more bodies, usually preserving the intervertebral discs. The affected area is often surrounded by calcified masses of detritus. Extensive hypertrophic changes are seen on the neighboring vertebræ.

Typhoid.—Typhoid in the bone is a localized destructive and proliferative process of long duration, usually occurring in early adult life. It is characterized by circumscribed areas of destruction in the ribs, the margins of vertebral bodies and occasionally the cortex of long bones. It may cause a local periostitis and at times extensive irregular periostitis indistinguishable from that of syphilis. In the

spine the first roentgen evidence usually appears at an interval of weeks or months after the onset of symptoms, when a small area of destruction may appear in the corner of a vertebra close to the disc. Subsequently coarse hypertrophic bridges may appear about this area or the intervertebral disc may be destroyed with a resulting fusion of the adjacent vertebræ.

Actinomycosis.—Actinomycosis causes a chronic osteomyelitis. It usually occurs in the jaw but may invade the vertebræ, ribs or ilium. It is characterized by its slow course and by the pronounced proliferation of bone with the resulting general increase in density.

Madura Foot.—Madura foot is a rare disease of the tarsal bones resembling actinomycosis. It runs a course of years with extensive destruction and new bone formation.

Oidiomycosis.—Oidiomycosis may attack the bone in severe cases. The roentgenogram will show extreme bone atrophy in involved areas, with more or less irregular destruction which suggests tuberculosis when it occurs in the region of a joint. Local areas of destruction may occur in the cortex with loose fuzzy strands of proliferating periosteum overlying them.

Leprosy.—Leprosy is characterized in its early stages by bone atrophy of the terminal phalanges and a variable amount of periostitis. As the disease progresses these phalanges disappear and there is a progressive involvement of the other phalanges.

Parasites.—Echinococcus and cysticercus cysts may occur in bones, giving an indefinitely oval rarefaction in the medulla which may be mistaken for osteomyelitis.

Phosphorus Poisoning.—Phosphorus poisoning causes a chronic osteomyelitis of the jaw, indistinguishable roentgenologically from the ordinary pyogenic form.

Yaws.—Yaws is a chronic tropical disease which manifests itself in the early cases (one to two years) in the form of multiple oval areas of rarefaction scattered through the long bones. These areas vary in size and degree of translucency. A characteristic finding is the presence of these cavities within the cortex often beneath the periosteum which may be slightly elevated and thickened over the lesion. The process also attacks the articular surfaces with erosion of the bone beneath the cartilage and considerable deformity if the process is extensive. In the chronic cases there is marked irregularity in size and outline of the bones, and considerable shortening if the epiphyses have been involved.

BONE TUMORS.

In the study of *bone neoplasms* it is particularly important to determine whether or not they are chiefly medullary or cortical and as far as possible whether or not there is involvement of the soft tissue. The most important question which one is called upon to decide is whether the lesion is benign or malignant. This may be a matter of considerable difficulty.

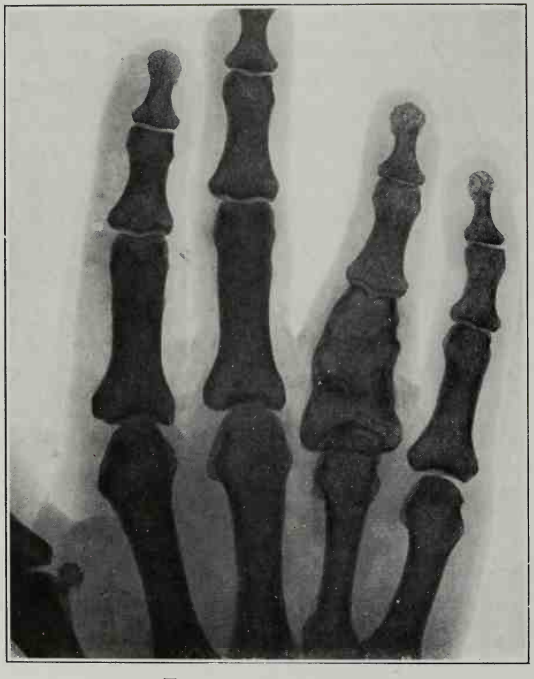

FIG. 40.—Enchondroma.

Benign Lesions.—Osteomata.—Osteomata are merely irregular extensions of normal bone into the surrounding tissues. They are characterized by their very slow development, by the fact that their structure is that of normal bone and that they blend into the bone at their site of origin. They are most commonly found near the end of the long bones in adults. They may consist of hook-shaped processes called exostoses or broad, rounded masses—true osteomata.

Enchondromata.—Enchondromata cause irregular eccentric enlargements of the bones. They are usually multiple and are most

common in the hands, feet and long bones. There is considerable distortion in the outline as a result of tumor growth with or without thinning of the cortex, and the trabeculæ of the medulla may be replaced by a homogeneous, putty-like shadow or by multiple small rounded areas of rarefaction. In extensive tumors the thinning of the cortex may be so extreme that it is reduced to small, thin flakes of bone on the periphery of the growth, which in the flat plate are

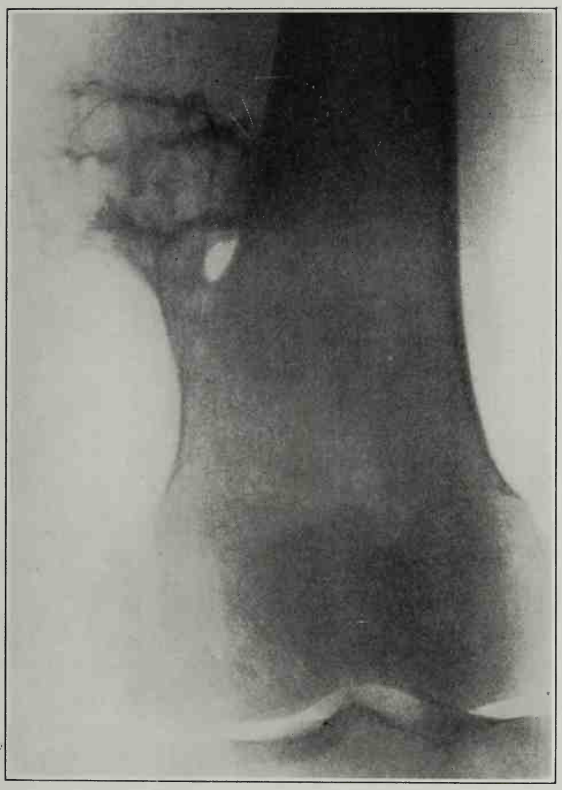

FIG. 41.—Exostosis of the femur.

projected upon the tumor and must be differentiated from calcification within the growth. These tumors are very often confused with giant-cell sarcomata.

Multiple Cartilaginous Exostoses.—Multiple cartilaginous exostoses are a hereditary anomaly of development, in which large cartilaginous outgrowths of diminished density and irregular outline appear in the region of the epiphyseal lines. These growths are multiple,

usually involving most of the epiphyses and cause considerable deformity and interference with the normal development of the bone.

Bone Cysts.—Bone cysts occur in the long bones and in the jaw. They are characterized by sharply defined, rounded or oval areas of rarefaction containing few or no trabeculæ. The process is entirely within the shaft, and spreads longitudinally in the medulla

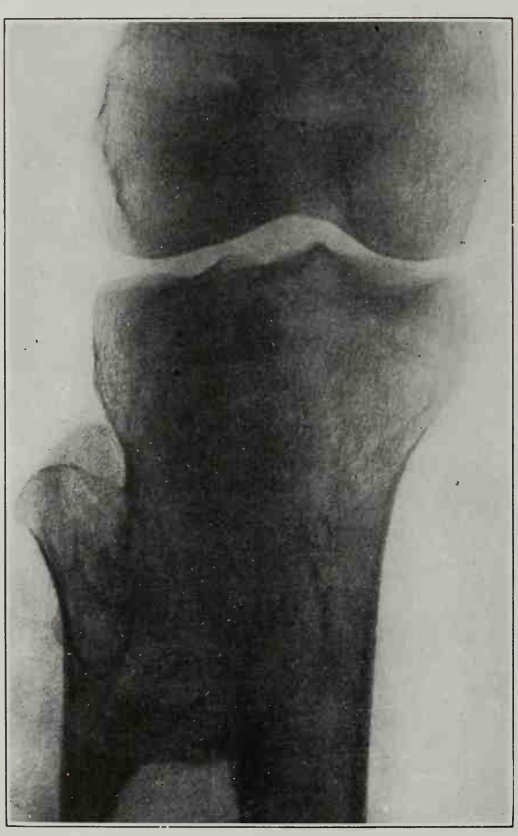

FIG. 42.—Multiple cartilaginous exostoses.

without involving the cortex which, however, may be considerably thinned from pressure. There is no deformity in outline unless a fracture has occurred. Spontaneous fractures are often the first indication of the presence of a lesion and they are usually followed by extensive callus formation.

Osteitis Fibrosa.—Allied to cystic disease is a rare condition which may involve one or all of the bones. It consists in the replacement

of the normal structure by irregular strands of trabeculæ enclosing multiple cysts which vary in size and shape. There is considerable expansion in the bone, and spontaneous fractures are common as a result of the thinning of the cortex. There is no periosteal proliferation.

Osteitis Deformans (Paget's Disease).—Osteitis deformans is a disease of middle age and beyond. It is a slowly progressive process which usually involves the bones of the lower extremity, the spine, clavicles and calvarium, but in rare forms may be limited

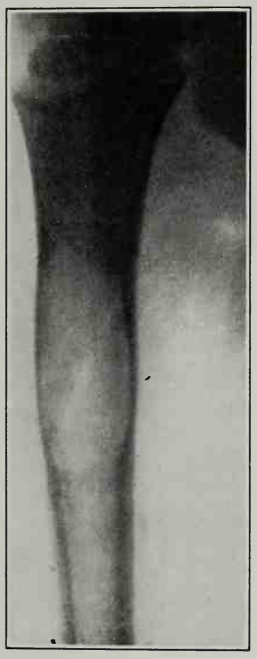

FIG. 43.—Bone cyst in upper end of humerus.

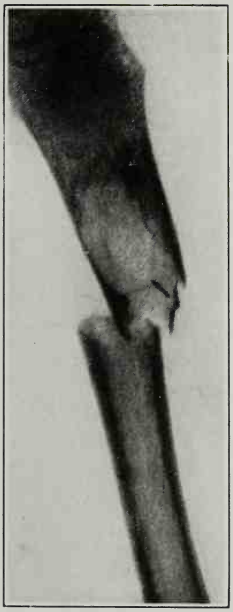

FIG. 44.—Bone cyst and fracture.

to one end of the tibia. It shows extensive thickening of the cortex on both sides, with enlargement and bowing of the bone and rearrangement of the trabeculæ into strands or bundles running longitudinally. The medulla shows mottled areas of rarefaction which usually extend into the epiphysis. This involvement of the epiphysis is important in the differentiation from lues, which very rarely affects the epiphysis in the same manner. In the skull this condition causes an increase in the size of the head as a result of expansion of the cranial bones, which show great thickening of both

tables and coarse mottling throughout the diploe. Marked calcification in the arterial walls is usually associated with this disease.

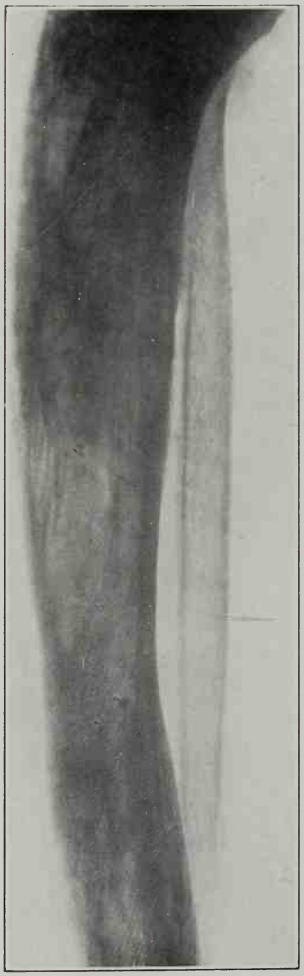

FIG. 45.—Paget's disease.

Malignant Lesions.—Sarcoma.—Giant-celled sarcoma is probably not a true malignancy. The lesions are usually benign but may at times become malignant. This tumor, which is of slow growth, occurs as an isolated lesion, usually near the end of a long bone or in the jaw. The growth is eccentric, that is, it causes asymmetrical enlargement of the bone and tends to balloon out the cortex rather

than to spread along the medullary canal. Ordinarily it does not break through the cortex. The mass of the tumor consists of irregular areas of rarefaction containing coarse trabeculæ, sometimes suggesting a mass of soap-bubbles.

Osteosarcomata are slowly growing masses which usually originate in the medulla of long bones or in the flat bones. Their characteristic is an early, extensive, irregular deposition of lime salts throughout the growth. They are not particularly malignant. They may be mistaken for an old osteomyelitis but the history will usually differentiate them.

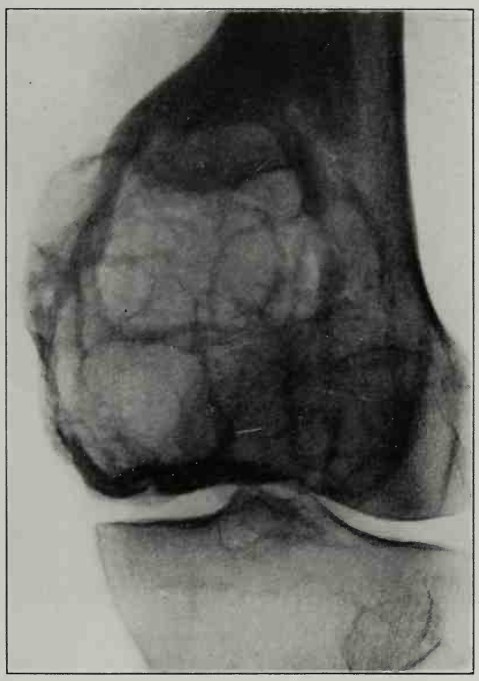

FIG. 46.—Giant-cell sarcoma.

Round or spindle-celled, medullary sarcomata are of very rapid development and metastasize early. They involve the shaft, often the greater part of it. Their appearance is that of extensive rarefaction with destruction of trabeculæ, early invasion of the overlying cortex and extension into the soft parts. Often there is a complete loss of bone substance in the area occupied by the tumor, the outline of which can be traced into the soft tissue. At times the

picture resembles that of a virulent osteomyelitis which should be differentiated by the history and clinical course.

Periosteal sarcomata are rapidly growing tumors which are extremely malignant and which originate from the periosteum, most commonly along the shaft of the long bones. In the earliest stages they may appear as a slight erosion of the cortex or a blister beneath the periosteum which is elevated by the growth. As the tumor increases, the shadow of its outline in the soft tissues becomes

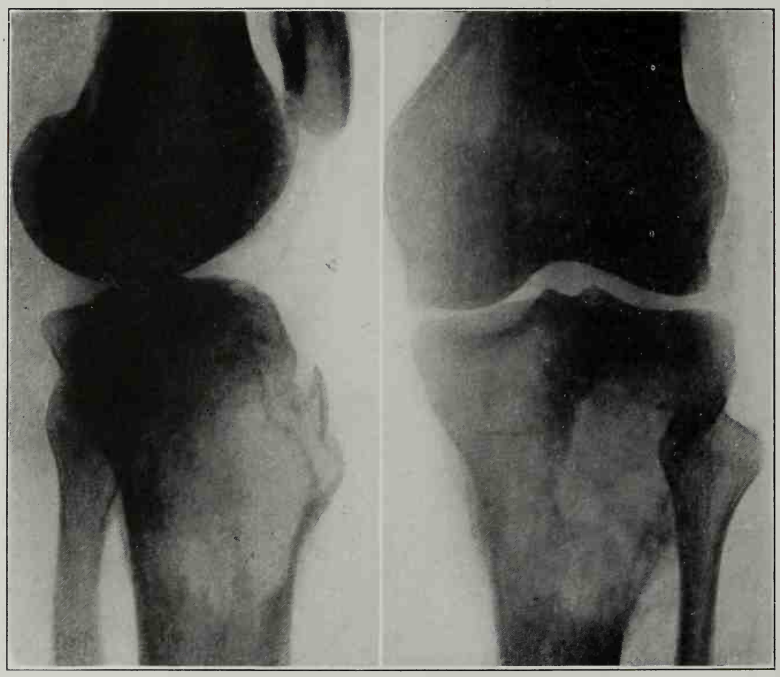

FIG. 47.—Round-cell sarcoma.

evident. A most characteristic finding is the presence of fine strands of calcified material radiating into the substance of the tumor and terminating freely. There may be erosion of the cortex which ends abruptly at the limits of the growth. The periosteum is usually thickened at the margins of the tumor and curves upward upon it ("*A*," Fig. 49). In the early stages careful examination of the entire periphery of the bone may be necessary to demonstrate the lesion.

Carcinoma.—Carcinoma is always metastatic and may involve any one or all of the bones. It may be identified by a moth-eaten appearance due to the irregular destruction of bone substance and its replacement by tumor mass. The cortex may be involved, but ordinarily only in the later stages. There is no periosteal reaction and no change in outline unless spontaneous fracture occurs.

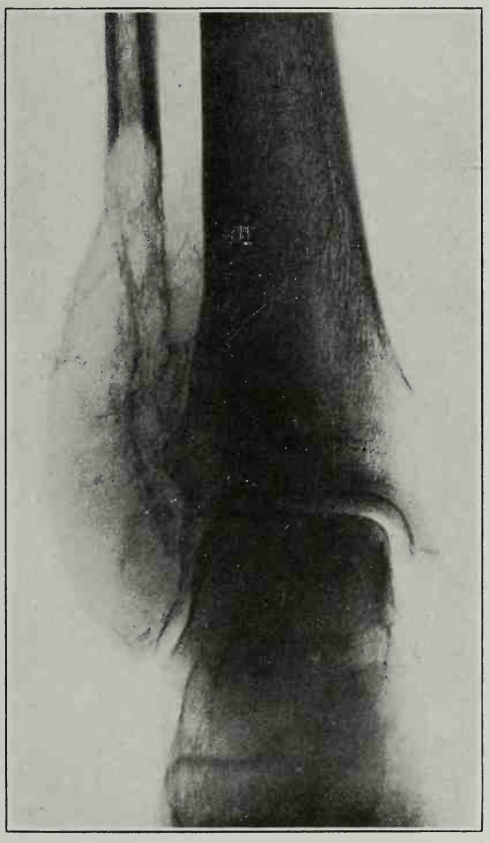

FIG. 48.—Medullary sarcoma of the lower end of the fibula.

In the skull it appears as irregular areas of bone destruction which typically are limited to the diploe and do not involve either table. When the spine is involved there is more or less extensive destruction of several bodies but ordinarily they do not collapse owing to the fact that the dense tumor tissue affords considerable support. This is of importance in the differentiation from tuberculosis and lues, in which collapse of the affected bodies is the rule.

There is a second form of metastatic carcinoma usually secondary to a tumor of the prostate or breast, which is of extremely slow development—cases having been seen ten years after the recognition of the primary disease. It is characterized by the extensive production of new bone in the vicinity of the growths. Its usual site is in

FIG. 49.—Periosteal sarcoma of the femur in a child. *A*, elevation of periosteum at edge of growth; *B*, spicules of bone radiating into tumor.

the spine and pelvic bones, which become greatly increased in density and coarsely mottled from the intermingled areas of rarefaction and condensation. The bones are sometimes enlarged and may be mistaken for osteitis deformans. The long history may also be suggestive of this condition. More careful inspection will show

that the picture is produced by adjacent areas of bone destruction and proliferation, with the latter predominating, and that there is no evidence of the rearrangement of trabeculæ into bundles, which is typical of Paget's disease. Furthermore, the distribution of the lesions is quite dissimilar. Osteitis deformans more commonly attacks the long bones and skull and rarely involves the spine, while this form of carcinoma shows a preference for spongy bone. The

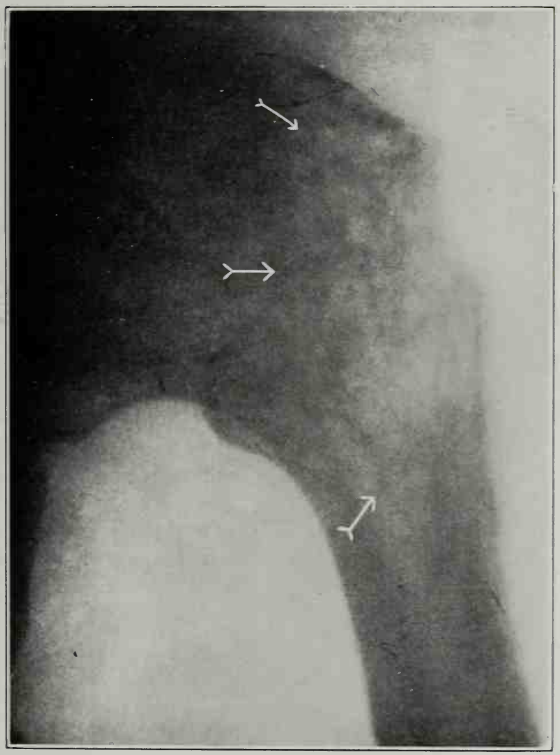

FIG. 50.—Metastatic carcinoma of the femur.

demonstration of a primary growth particularly in the prostate should be conclusive.

Rarer Bone Tumors.—Any type of tumor may be encountered in the bones and the roentgen appearance of different pathological entities is naturally very similar, as they are manifested only by irregular areas of bone destruction which are not characteristic of any particular neoplasm. They are commonly diagnosed as carcinoma roentgenologically. Under this heading come hypernephroma,

myeloma, myxoma, fibroma, etc. The age of the patient and the distribution of lesions may be helpful.

Hypernephroma.—Hypernephroma occurs as multiple small areas of rarefaction with loss of trabeculæ and no attempt at new bone formation. It may be distributed throughout the skeleton and is particularly common in the skull, sternum, ribs and bodies of vertebræ.

FIG. 51.—Metastatic sarcoma of the skull in a child.

Myeloma.—Myeloma is a low-grade malignancy of slow evolution which typically causes small multiple areas of rarefaction, usually limited to the flat bones, although extensive single lesions have been observed in long bones. Owing to its slow growth, deformities in outline occur as a result of thinning and expansion of the cortex overlying the growth. For the same reason spontaneous fracture is fairly common. Its appearance resembles that of giant-cell sarcoma or carcinoma, although the areas are usually smaller, more rounded and more sharply defined. It is accompanied by

the presence of Bence-Jones bodies in the urine. Some cases have responded well to roentgen therapy.

Chloroma.—Allied to myeloma and the leukemias is a form of tumor which occurs in the skull, usually in the vicinity of the orbit,

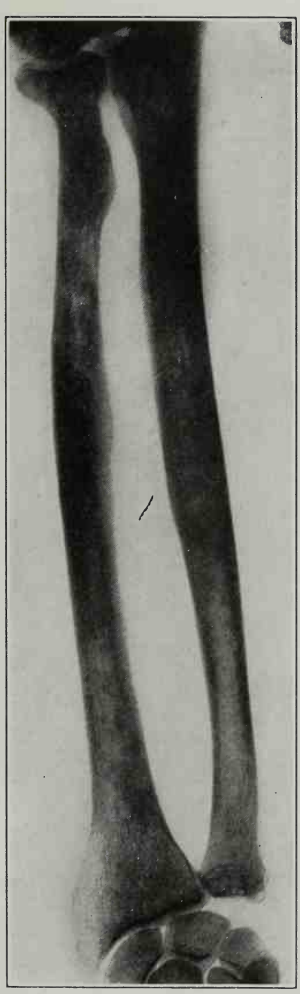

FIG. 52.—Multiple medullary myeloma.

the vertebræ and ribs. It is seen most frequently in childhood and occasionally after forty. It runs an acute course and is invariably fatal. The roentgen appearance in children is that of increased intracranial pressure. The sutures are widely separated and the

skull may present thin areas corresponding to the convolutions of the brain. The invaded bones show irregular areas of rarefaction. There is no evidence of repair. The process presents an appearance closely resembling that of multiple myeloma and metastatic carcinoma.

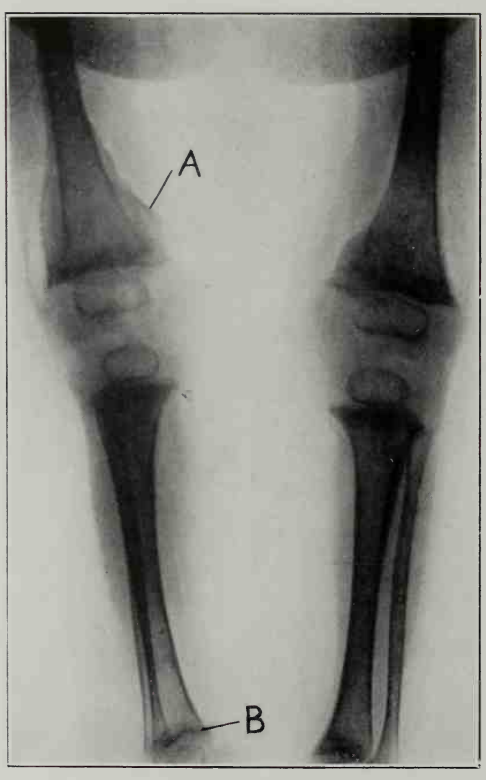

FIG. 53.—Scurvy, well advanced. Note the organized hemorrhage about the shaft at *A* and the white line at *B*.

Myxoma.—Myxoma is a slowly growing tumor which usually involves a single long bone. It causes irregular enlargement of the whole shaft, irregular rarefaction of the medulla and thinning of the cortex. Pathological examination may be necessary in a differential diagnosis.

DISEASES OF NUTRITION.

Scorbutus.—This condition is commonly seen during the first years of life and may or may not have an associated rickets. The

earliest evidence of its presence is a white line in the shaft margin of the epiphyseal zone. This line is thinner, more dense and more sharply defined than the one seen in rickets. Later in the clinical

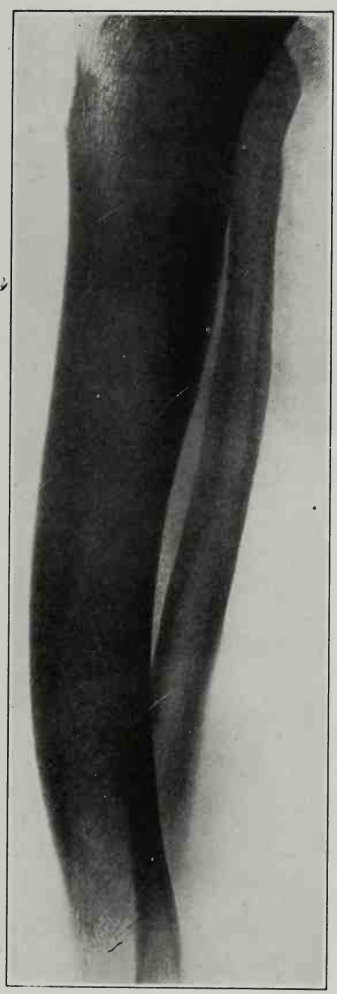

FIG. 54.—Bowing of the tibia in the adult, due to rachitis.

course subperiosteal hemorrhages appear as more or less extensive irregular elevations of the periosteum over the entire length of the shafts of the long bones. In severe cases the hemorrhage may be sufficient to produce separation of the epiphysis. The final process

consists of organization of the clot which produces a shadow of considerable density about the shaft.

Differential diagnosis is from lues and osteomyelitis. Lues is more often a generalized process, the periosteum is less elevated and epiphyseal dislocation does not appear. In osteomyelitis there is destruction of the shaft which is unaffected in scorbutus, and the clinical picture is, of course, quite characteristic.

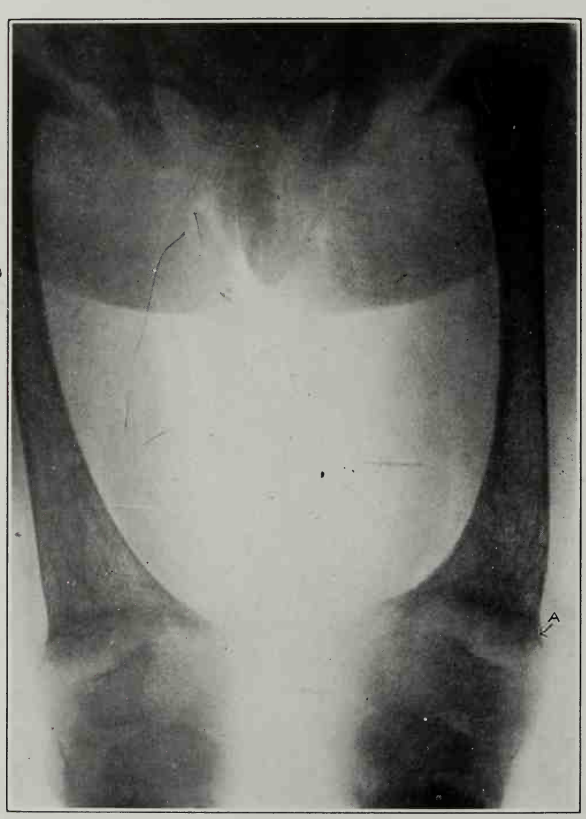

FIG. 55.—Active rachitis.

Rickets.—This is a disease usually occurring during the first dentition. It shows in the roentgenogram a flaring and widening of the diaphysis above the epiphyseal line; the zone between shaft and epiphysis is increased in thickness, with ragged, fringy margins (*A*, Fig. 55). The shaft side of the epiphyseal line may appear as a broad white line, as a result of the deposit of lime salt. The

shaft may be bowed and the cortex considerably thickened on the concave side of the curve. Mild periosteal proliferation sometimes occurs. There may be areas of decreased density in the cranial bones along with prominence of the frontal and parietal bosses. In the form which comes on during adolescence there is irregular

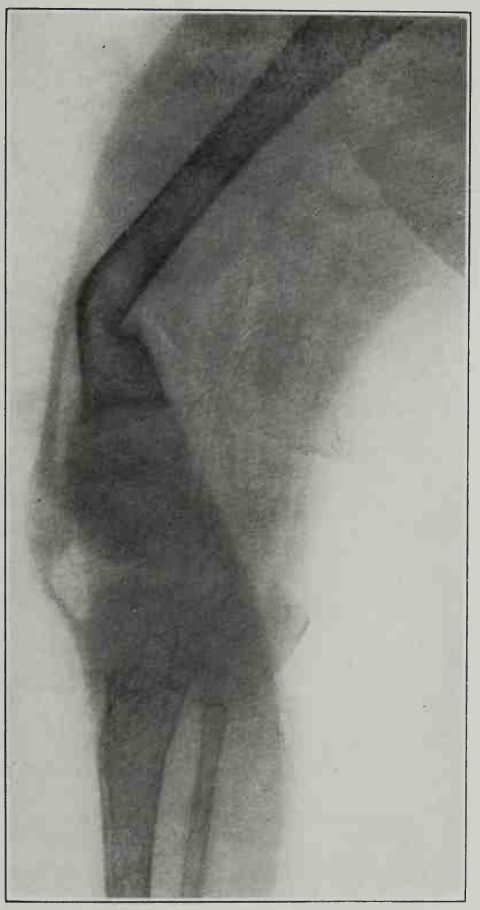

FIG. 56.—Osteogenesis imperfecta.

rarefaction and enlargement of the long bones, resulting in disturbance of the weight-bearing lines, as, for example, coxa vara and genu varum.

Achondroplasia (Chondrodystrophy Fetalis).—The bones in this condition are shortened, compact and at times bowed. The epiphy-

seal line is very thin and sharply defined and closes considerably earlier than the normal. This results in an adult whose long bones are very much shortened, with corresponding loss of height. This process is said to involve only those bones in which ossification has begun before the sixth month.

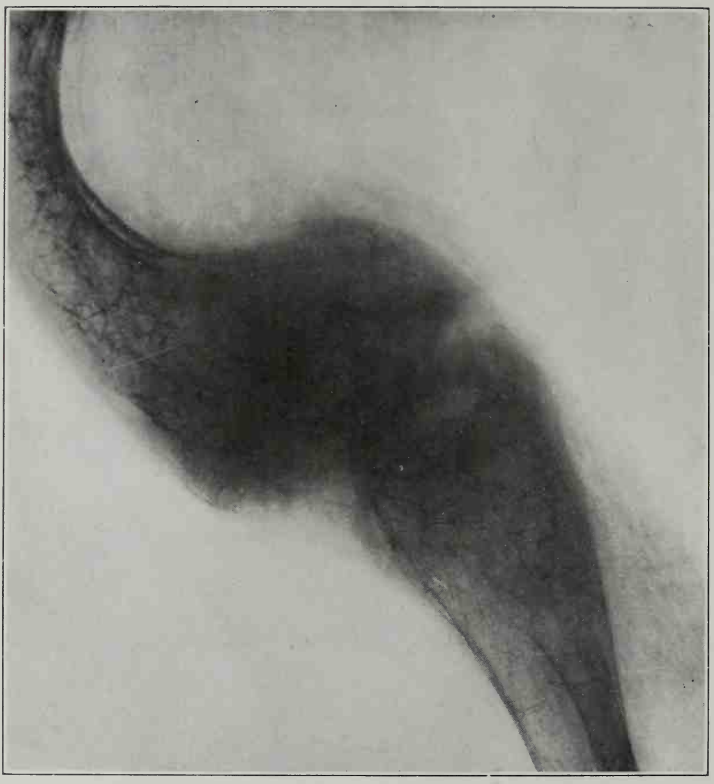

FIG. 57.—Osteomalacia involving the long bones of a child.

Osteogenesis Imperfecta (Fragilitas Ossium, Periosteal Dysplasia or Osteopsathyrosis).—In the infantile form of this disease the bones show great diminution in lime salts and thinning of the cortex without changes in size. This results in a weakening of the structure of the bones and multiple spontaneous fractures occur, usually followed by a fair amount of callus formation. A characteristic feature is the appearance of the skull—the calvarium of which is composed of a great number of small plaques of bone irregularly united by fibrous tissue, presenting a mosaic appearance.

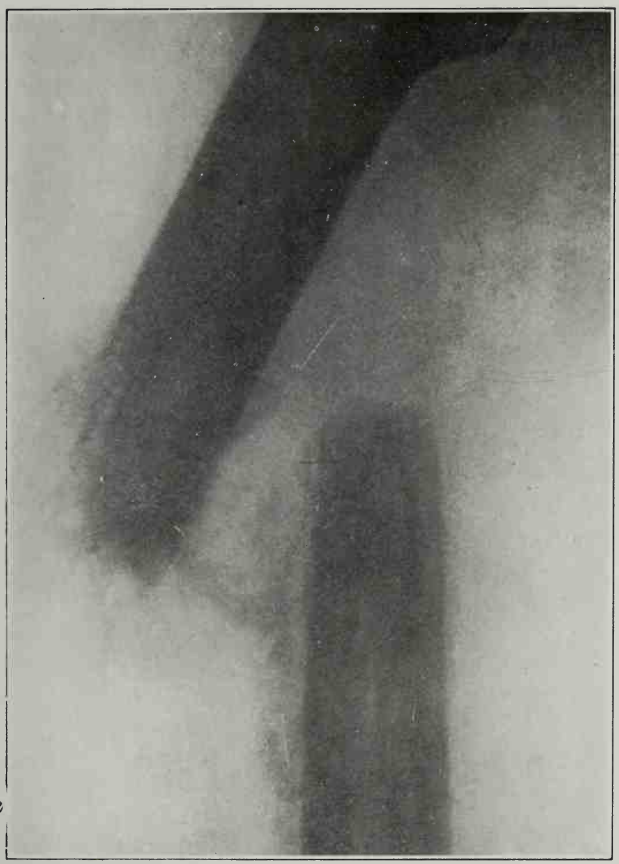

FIG. 58.—Osteomalacia, with pathological fracture in adult female.

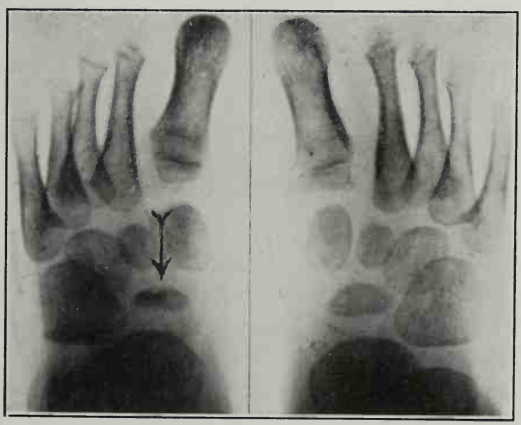

FIG. 59.—Kœhler's disease. Flattened scaphoid indicated by arrow. Normal foot on right.

In the adult form the bones are nearly normal in size and calcium content but usually present considerable deformity as a result of the multiple spontaneous fractures which the patient has suffered.

Kœhler's Disease.—A rare condition affecting the ossification center of the scaphoid in the foot. Most of the cases have been seen in boys between the ages of three and nine. The roentgen appearance is quite striking, consisting of compression and irregular increase in density of the bone. (Fig. 59.) In one of

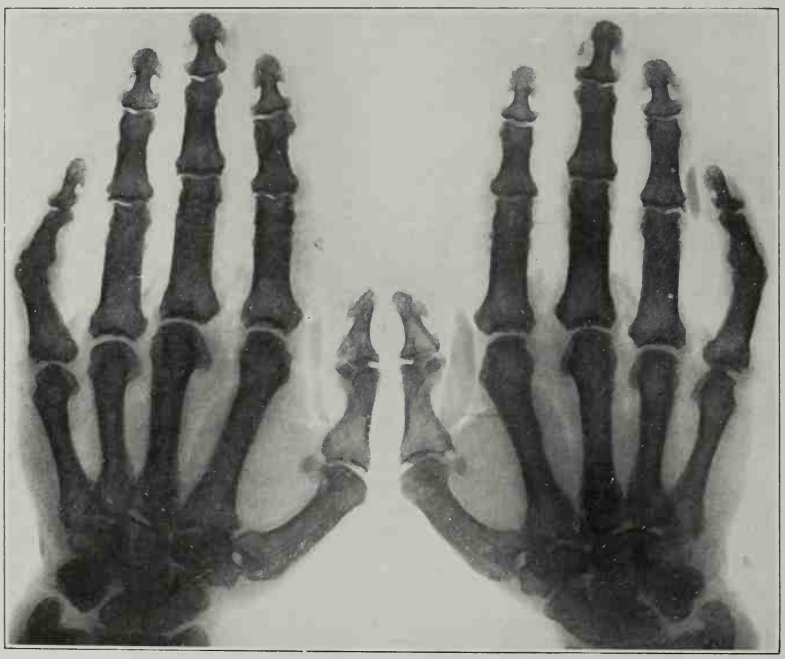

FIG. 60.—Acromegaly. Note the enlargement of the terminal phalanges.

Kœhler's cases there was a similar process in the patella. Neither trauma nor infection are responsible for the etiology of the condition which resembles osteochondritis deformans and may be caused in the same manner.

Acromegaly.—Acromegaly, in addition to the characteristic changes in the skull, gives rise to a general enlargement of the skeleton. The texture of the cancellous bone throughout the individual becomes coarse and heavy. There is also clubbing of terminal phalanges.

Hypertrophic Pulmonary Osteoarthropathy.—The first stage in this process is enlargement of the soft tissues of the ends of the fingers, so-called club fingers. Later proliferation of the periosteum, which

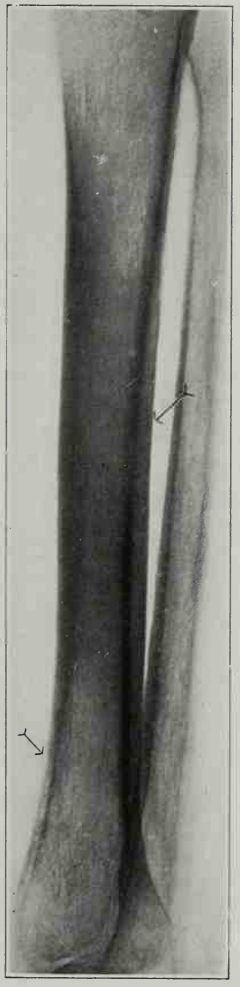

FIG. 61.—Hypertrophic pulmonary osteoarthropathy.

is difficult to distinguish from that of lues, appears along the metacarpals and phalanges, particularly those of the fifth finger and toes, and frequently about the distal end of the long bones. Rarely the process may involve all the periosteum of the long bones.

As a result, these bones have a thickened cortex and in the later stages are increased in width.

Osteomalacia.—This is a condition of extreme and irregular diminution in the density of the bones. There is usually considerable deformity due to bending and spontaneous fractures with poor callus formation. This condition may result from any one of several causes and is closely related to osteogenesis imperfecta and osteitis fibrosa—in fact they may be classified as forms of osteomalacia.

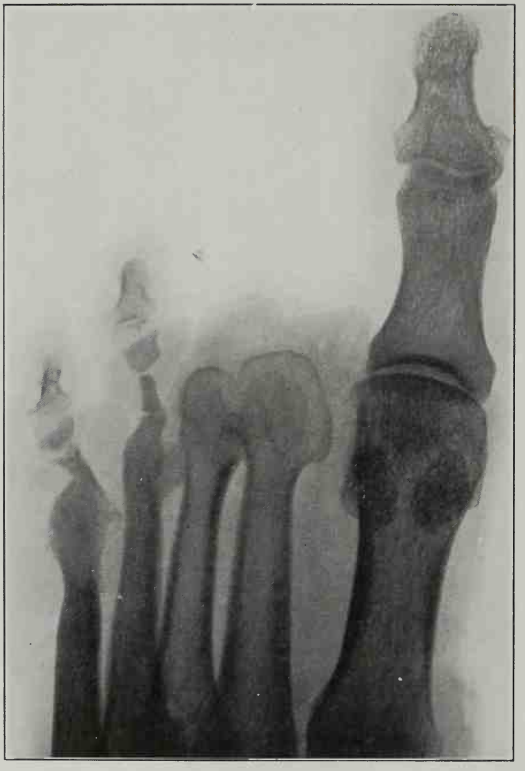

FIG. 62.—Trophic changes following old fracture of lumbar spine. Previous operative removal of phalanges of second and third toes.

TROPHIC CHANGES.

Senile Atrophy.—The bones of old people, of course, share in the general atrophic changes of the body. They are less dense, the cortex is thinned, and the spongy bone becomes delicate in structure. Ultimately, there is a gradual decrease in the size of the bone. The

process begins in areas devoid of muscular attachments, and involves most extensively the flat bones, especially the calvarium, pelvis, and scapulæ.

Halisteresis.—The term "bone atrophy" has been commonly, though erroneously, employed to designate a process of decalcification which is probably trophic. An area of bone following injury, fixation, or infection in its vicinity may lose a large portion of its lime salts, and become radiolucent. This process may be acute, the so-called "acute bone atrophy" coming on within a few days after injury; but it more commonly requires from ten days to several weeks for its development. It occurs in two forms—the spotted and diffuse. The spotted form consists of multiple small areas of rarefaction from a millimeter to a centimeter in diameter scattered through the affected bony tissue. These areas may remain discrete with fairly normal bone substance between them, giving a picture which is similar to that of metastatic malignancy, or more commonly the intervening bone gradually becomes rarefied, producing a diffuse decalcification throughout the affected area. The diffuse is commonly seen in extremities after fixation for some weeks, or involving the bones about an infected joint or the bones of the hands and feet in cases of infection of the overlying soft parts. As its name implies, it is a uniform loss of density which ordinarily includes several bones either wholly or in part.

Changes Associated with Nerve Lesions.—The most common example of this condition is the Charcot joint which occurs in tabes and syringomyelia where there is complete disorganization of the joint with extensive destruction of the articular ends of the bones and the occurrence of multiple loose fragments scattered through the joint. There is no diminution in density in the affected bones, in fact there may be an increase.

The shrinkage and ultimate disappearance of the terminal phalanges in leprosy has been mentioned. Bryan has recently pointed out that in long-standing cases of fractured vertebræ, the phalanges of the toes may progressively diminish in size and ultimately disappear. There is also erosion of the articular ends of the metatarsals. A similar process has been observed in a case of diabetes without obvious nerve changes.

A TABULATION OF THE FINDINGS IN THE MORE COMMON BONE LESIONS FOR USE IN DIFFERENTIAL DIAGNOSIS.

Osteomyelitis.

1. Usually a single lesion.
2. Both destructive and proliferative.
3. A disease of the shaft, involving the epiphysis—rarely the joint.
4. Produces bone atrophy and sclerosis.
5. Usually starts in the medullary portion and involves the cortex, periosteum, and soft tissue.
6. Occurs at any age.
7. Enlargement and deformity of the bone.

Syphilis.

1. Usually a multiple process.
2. Usually proliferative. The gummatous form, which is rare, is both proliferative and destructive.
3. Usually a disease of the shaft, but rarely it involves the joint and epiphysis.
4. Usually confined to the periosteum, but may involve the cortex; does not cause bone atrophy.
5. May appear at any age.
6. There may be enlargement and considerable deformity of the bones.

Periosteal Sarcoma.

1. Always single.
2. Proliferative.
3. Involves the shaft only, as a rule—rarely invades the epiphysis; never enters a joint.
4. Invades the soft tissues in the immediate neighborhood, presenting characteristic ray-like formation. Bone atrophy is absent.
5. Common in young adults.

Carcinoma.

1. Multiple lesion.
2. Usually purely destructive; rarely there is bone proliferation about the invaded area.
3. Attacks the medulla and cortex of the long and flat bones; the periosteum and joints are not involved.
4. A disease of adults.
5. In the proliferative type, the bones may be enlarged and deformed.

Tuberculosis.

1. Usually a single lesion.
2. A destructive process.
3. A disease of the joints and epiphyses.
4. Rarely invades the shaft and soft tissues; the neighboring bones show marked atrophy. The periosteum is not involved.
5. More common in children.
6. The size of the bone may be small, due to interference with growth.

Paget's Disease.

1. A multiple lesion.
2. Proliferative.
3. Involves the shaft and epiphysis—the joints are not affected.
4. Late adult life.
5. Overgrowth of the bony structures and abnormal trabeculation; the soft tissues are not invaded.

Giant-cell Sarcoma.

1. Single lesion.
2. Destructive type.
3. Involves the medullary portion of the shaft; the cortex may be thin but is not invaded; the joints and soft tissues are unaffected.
4. Childhood and young adults.
5. The bone is locally deformed.

Bone Cyst.

1. Single lesion.
2. Purely destructive.
3. Located in the medullary portion of shaft; does not invade the cortex, joint, or soft tissue.
4. Children and young adults.
5. The bone is not deformed.

MEDULLARY SARCOMA.

1. Single lesion.
2. Purely destructive in the bone.
3. Involves the shaft, rarely the epiphysis; never the joint.
4. The cortex of the bone is destroyed and the soft tissues invaded.
5. Usually in young adults.

OSTEOMA.

1. Usually a single lesion.
2. Purely proliferative.
3. Arises from the cortex; never invades the bone.
4. Common in children and young adults.
5. There may be some deformity of bone from pressure; structure of the growth resembles normal bone.

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CHAPTER V

THE SKULL.

ROENTGENOLOGY of the skull, its contents, sinuses, mastoids and teeth has become a field of its own. There is naturally a close association between the teeth and sinuses, and the two should always be studied together. The bones of the skull are subject to fractures and diseases affecting the skeleton generally, which have already been considered.

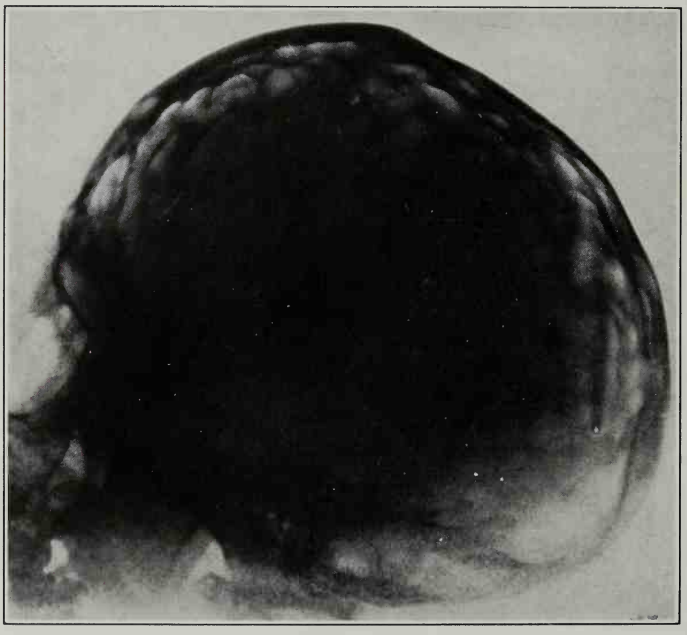

FIG. 63.—Oxycephalus. The suture line and the grooves of the vessels are obliterated.

There is great variability in the time and sequence of closure of sutures—normally they are open at least until thirty-five. The posterior end of the sagittal begins to close at forty, and the coronal

at fifty. Closure early in life (craniostenosis) gives rise to deformities in shape, depending upon the sutures involved. Three general forms are recognized:

1. Turret head (one form of which is oxycephaly) which is short, broad and abnormally high. The roentgen picture is striking, as in addition to the unusual shape with a projection at the bregma and bulging of the temporal regions, there is marked thinning of the vault with deep convolutional atrophy which may progress to perforation. Prominence of the eyes and blindness are early symptoms.

2. Scaphoid head, which is abnormally long and narrow.

3. Slanting head, showing marked asymmetry in any one of several planes.

Hydrocephalus.—Hydrocephalus is perhaps the commonest brain condition with which the roentgenologist has to deal in children. There is enlargement of the vault out of all proportion to the base. The picture is one of chronic intracranial pressure—enlargement and great thinning of the vault of the skull, with exaggeration of the convolutional depressions and often separation of the sutures. Flattening of the sella is fairly common. In the form due to lues there is less thinning of the skull and a strikingly short base.

Tumor.—Brain tumor rarely gives direct evidence of its presence. Localized erosion of the calvarium over the lesion or increased density due to new bone formation by the dura overlying it or, very rarely, calcification in the mass itself may help to localize the process. In 90 per cent. of the cases all that appears on the plate is the evidence of intracranial pressure and the common findings are compression or destruction of the clinoid processes, enlargement of the bloodvessel channels distributed to the affected area and, at times, increased impressions of the cerebral convolutions. In severe cases separation of one or more suture lines may be present.

Tumors of the cerebellopontine angle by forward extension, cause thinning and forward bending of the posterior clinoid processes. They may also cause dilatation of the internal auditory meatus, usually unilateral.

Mention should be made of cholesteatoma, a benign tumor found in association with the membranes of the skull, resembling endothelioma. It may produce an extensive destruction of bone. It is most common about the base and in the temporal regions.

Chloroma, related to myeloma and leukemia, is a form of growth found characteristically about the orbit, causing irregular bone destruction.

Soft tissue tumors may cause erosion of the bone beneath them, as occurs in the case of circoid aneurysm.

Subdural Hemorrhages.—Subdural hemorrhages cannot be diagnosed on the roentgenogram. Thin areas in the temporal region or areas of increased density in the parietals are often erroneously pointed out as hemorrhages.

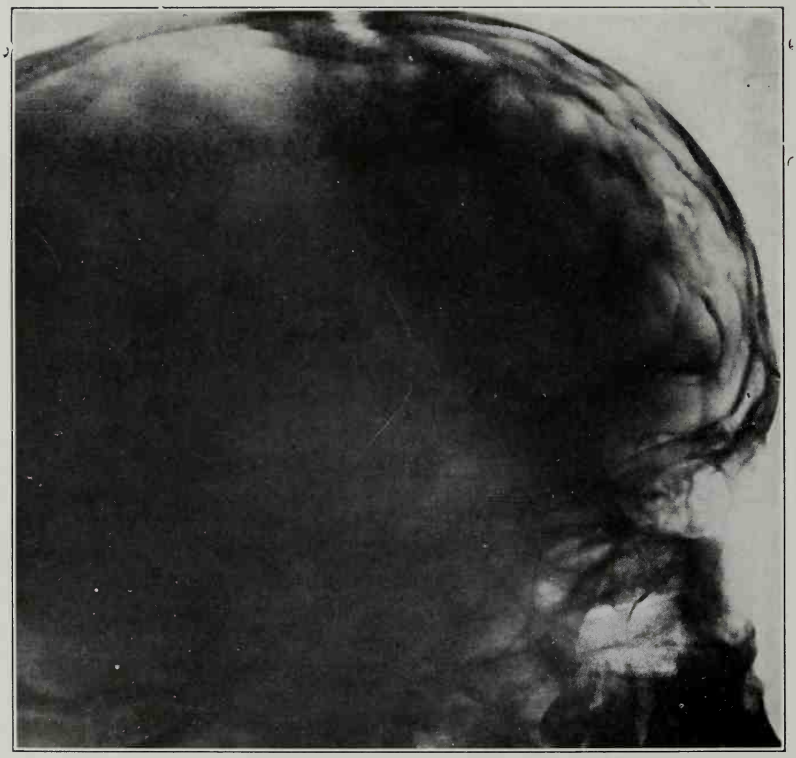

FIG. 64.—Tumor of the brain located in the frontal lobe. The plate shows localized pressure atrophy.

Sella.—True lateral views, preferably stereoscopic, are essential for the proper observation of the sella. It is subject to considerable variation both in size and shape, of which the latter is the more important. As already noted, deformity of the posterior clinoids may occur as a result of tumor in any portion of the brain. Hypophyseal tumors cause a ballooning of the sella with thinning of the floor and usually of both anterior and posterior clinoid processes. Associated with these changes may be seen more or less enlargement

of the sinuses, elongation of the mandible and general enlargement of the bones, particularly those of the hands and feet. Supracellar tumors cause a depression of the anterior clinoid processes and sharpening of their tips. The clinoids occasionally meet, bridging in the roof of the sella. Attention has been called to the fact that this is a common occurrence in epilepsy and sterility. (Faulty technic in securing views of the sella which are not true laterals may cause an appearance of roofing which a true lateral will correct.)

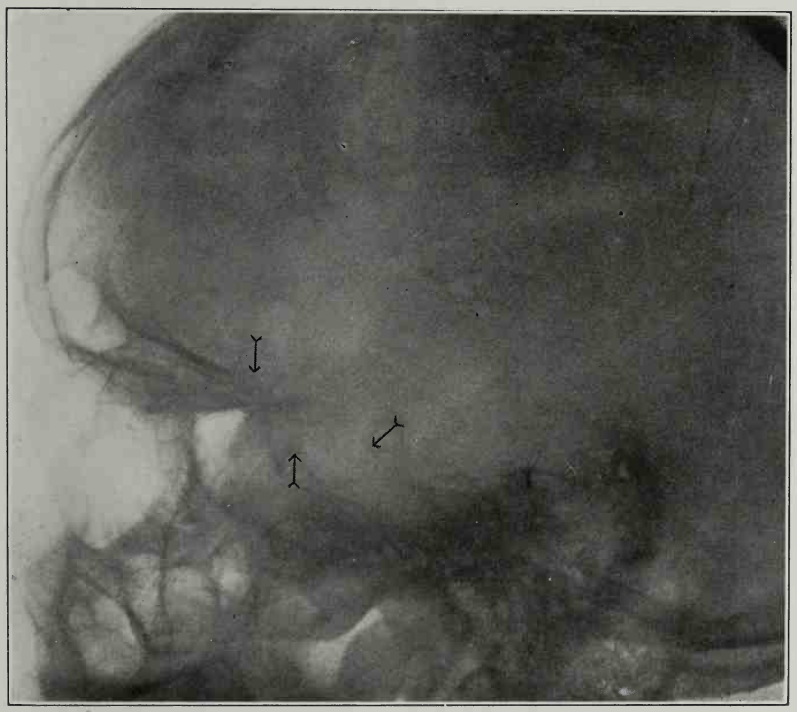

FIG. 65.—Pituitary tumor. The sella is enlarged and its floor destroyed.

Calcified Pineal Glands.—Calcified pineal glands are frequently seen in individuals over thirty. They appear as dense white spots a millimeter or two in diameter located in the mesial plane several centimeters above the mastoids. They are usually without significance, but when large and irregular may represent calcification in a tumor of the pineal.

Sinuses—For a proper study of the sinuses anteroposterior, lateral, and vertical projections are necessary. The anteroposterior

plate, in addition to the outline of the sinuses themselves, affords some evidence of the shape of the septum, size of the turbinates and relative depth of the floor of the nose and the floor of the antra. The lateral plate is particularly useful in checking up the antero-posterior of the frontals to determine their depth and the thickness of their walls. Teeth or foreign bodies in the antra may be well

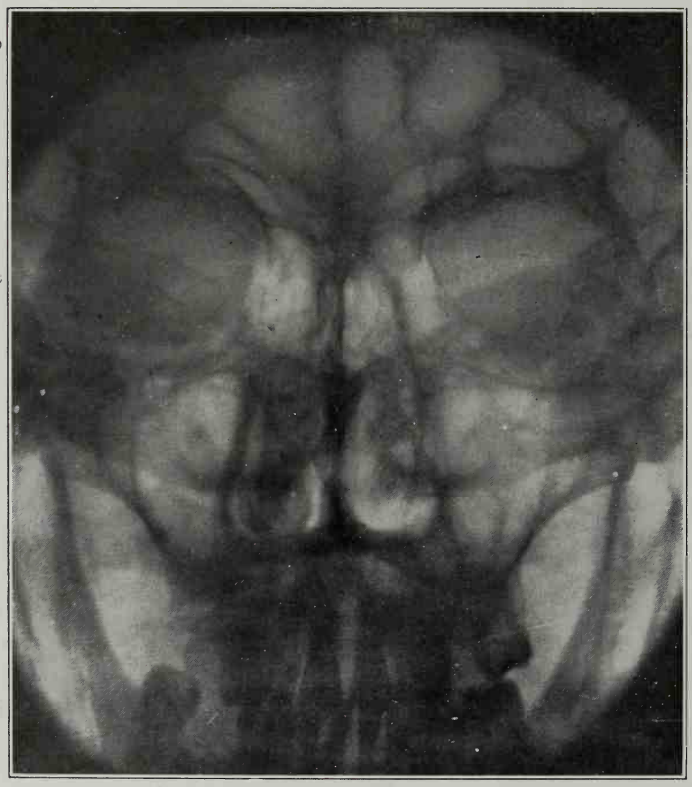

FIG. 66.—Very large sinuses. Anatomical variations.

projected in this view which often gives a clue to the condition of the sphenoidal sinus, but is of little value in the study of the ethmoids The vertical projection outlines the sphenoidal sinus very well.

The normal sinus, because of its air content and thin walls, appears as a more or less darkened area with sharply defined edges. Any change in the amount of air contained within it or in the thickness of its walls will be recorded as a change in density on the plate,

and both these factors must be considered in making a diagnosis. This is particularly true in the case of the frontals, where a degree of density which is normal for one individual may be quite pathological in the case of another whose air space is larger and walls thinner and whose sinuses should therefore appear darker. For the recognition of pathology, it is essential to compare the two sides and to have a fairly definite mental picture of the appearance of the normal sinus. In the study of the frontals both anteroposterior and lateral views must be combined.

FIG. 67.—There is a considerable area of calcification in a tumor of the pineal gland. The ventricles have been tapped, the fluid drawn off and air allowed to replace it. The outline of the tumor then becomes visible.

A general haziness with a slight increase in density in one or more sinuses usually means thickening of the lining membrane. This may be corroborated in the case of the frontals by the additional evidence of thickening of the septal markings which become hazy and are surrounded by an indefinite zone of slightly increased density, as contrasted with the sharply outlined normal septa. This general thickening may involve only one sinus, all of the sinuses on one side, or those of both sides. In the last condition, some difficulty may

arise from the fact that comparison of opposite sides is impossible and the roentgenologist must fall back upon his empirical knowledge of what the normal should be.

Granulations, pus or tumors produce a shadow of greater density, which usually obliterates the sinus completely. Their shadows are identical in every respect, so that it is usually impossible to tell which one is responsible for the shadow on the plate. When there is a fluid exudate in a sinus it is often possible to make out a fluid level in the suspected cavity upon a plate taken with the patient upright. However, the absence of a fluid level does not rule out pus.

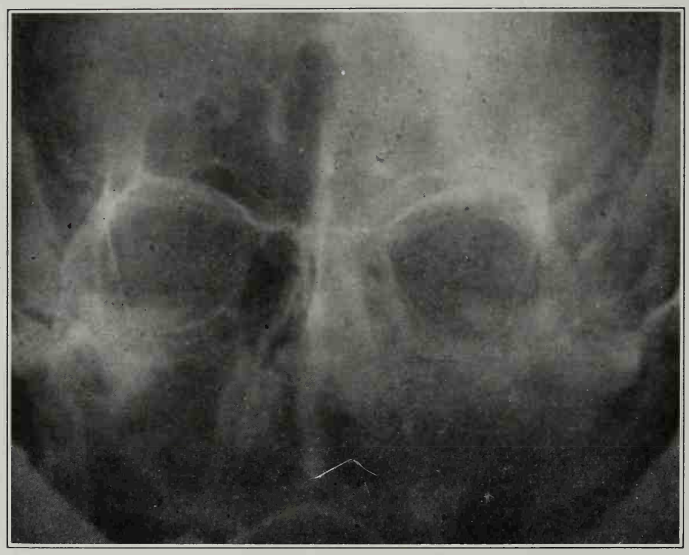

FIG. 68.—Sinusitis. All of the sinuses on the left side are dull.

Tumors of the sinuses will ordinarily give some evidence of their nature by erosion or invasion of the walls or adjacent bones. Very rarely a sinus or portion of the orbit will be occupied by a dense osteoma. Absence of frontal sinuses is fairly common and must be differentiated from thickening which has obscured the margins and obliterated the outline of a well-developed sinus. A lateral view will show no evidence of a sinus and no room for it at the base of the frontal. Careful inspection of the anteroposterior view should show the presence of bone structure in the suspected area.

It must not be forgotten that a sinus may be found filled with mucoid material at operation and yet cast no abnormal shadow on

the plate. In fact, mucoceles by erosion of the bone overlying them often appear as areas of diminished density.

Polypi can sometimes be visualized in the frontals and antra as rounded areas of slightly increased density. The entire sinus will usually appear somewhat hazy as a result of the thickened membrane.

A dense fusiform shadow may overlap the septum in a case of gumma of the septum.

The patency and course of nasal ducts may be determined from roentgenograms made with opaque probes *in situ*.

Mastoids.—Plates of both sides should always be taken as a routine for purposes of comparison. Normally the cells are bright and clear with sharply outlined walls. The broad grooves of the lateral sinus can usually be traced down across the mastoid as a streak of diminished density. In an acute mastoiditis there is general haziness of the affected cells and blurring of their margins, followed later by destruction of the cells and loss of their outlines, which are replaced by an indefinite area of increased density. In chronic cases there is more or less absence of cells and a variable degree of sclerosis. Occasionally the mastoid cell fails to develop and the finding in these cases may resemble those seen in chronic mastoiditis; but this condition is usually bilateral, and the shadow of the lateral sinus is nearer that of the auditory canal.

Teeth.—The roentgenologist should have a general knowledge of the development, anatomy and pathology of the teeth, for he will surely be called upon to do a certain amount of dental roentgenology. An understanding of the course of dentition is helpful not only in the interpretation of dental conditions in children and adults but also in the determination of the ages of children. The following table from Thoma can be relied upon as a working basis:

	Calcification begins.	Calcification complete.	Eruption.	Shed.
Temporary.				
Central incisor	....	1½ years	6 to 8 months	7 years
Lateral incisor	....	1½ "	1 to 9 "	8 "
Cuspid	....	2 "	17 to 18 "	12 "
First molar	....	20 months	14 to 15 "	10 "
Second molar	....	20 "	18 to 24 "	11 "
Permanent.				
Central incisor	1 year	10 years	7 to 8 years	
Lateral incisor	1 "	10 "	7 to 8 "	
Cuspid	3 years	12 "	12 "	
First bicuspid	4 "	12 "	10 "	
Second bicuspid	5 "	12 "	11 "	
First molar	Before birth	9 to 16 "	6 "	
Second molar	5 "	17 to 18 "	13 "	
Third molar	9 "	18 to 20 "	18 "	

The importance of good technic in dental roentgenology must be insisted upon. This includes adequate exposures with the least possible amount of distortion, preferably from several angles and the use of both plates and films.

Anomalies of development, irregularity of eruption, misplaced and unerupted teeth are perhaps the most frequent examples and the diagnosis is obvious. Impaction, which is particularly common in the molars, is a common finding. The presence of retained temporary teeth is readily recognized.

FIG. 69.—Multiple pus pockets involving the roots of the lower molars and bicuspids.

In adult teeth the roentgen examination is often of value in demonstrating fracture of the teeth below the gum level, the extent of carious processes, and in determining the extent and position of root canal fillings and the results of operative procedures. Pulp stones are often revealed in the pulp cavities. They are small, round, dense masses frequently multiple, which form in the pulp chamber of one or more teeth. They have been accused of being the cause of severe neuralgias. Inasmuch as they are frequently seen without symptoms, their significance is questionable.

The most important pathological conditions with which the roentgenologist has to deal are, of course, pyorrhea and alveolar abscess,

Pyorrhea.—Pyorrhea in its early stages gives little roentgen evidence aside from a slight increase in the width of the dark line

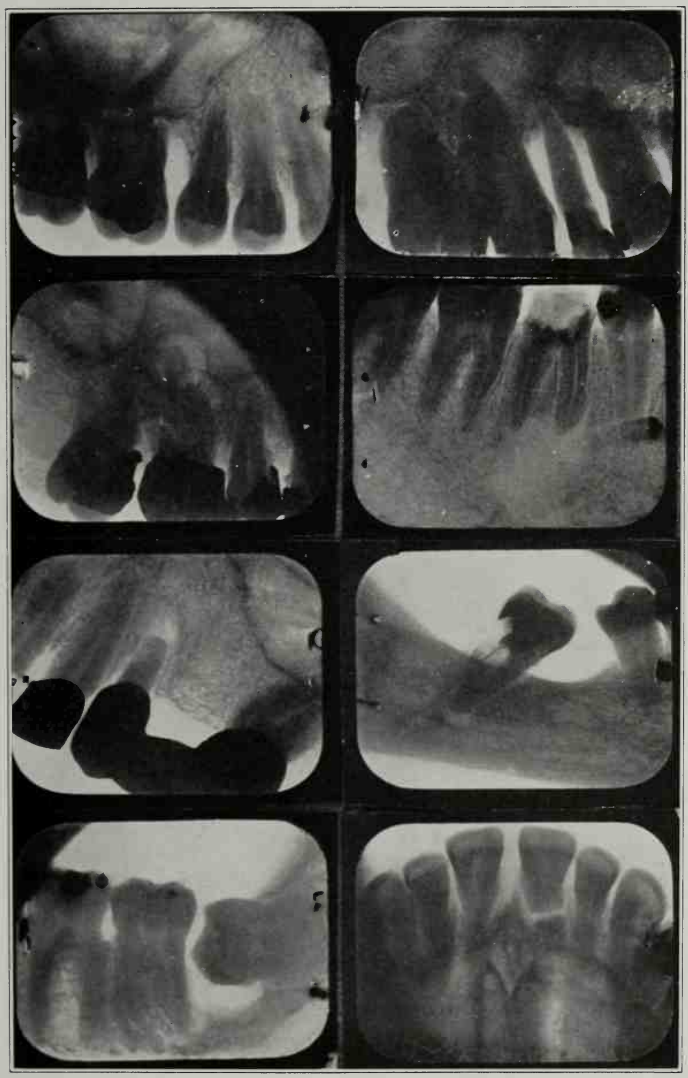

FIG. 70.—*1*, pyorrhea pocket about the mesiobuccal root of the left upper first molar; *2*, advanced Rigg's disease, with absorption and recession of the alveolus, but without definite pyorrhea pockets; *3*, chronic abscesses at apices of palatal and mesiobuccal roots of the left upper first molar; *4*, osteomyelitis arising from the roots of the left lower first molar; *5*, proliferative inflammatory granuloma, with central softening at the apex of the right upper second bicuspid; *6*, devitalized left lower molar showing caries, root canal fillings and small apical granuloma; *7*, impacted right lower third molar, with pus pocket; *8*, small pyorrhea pockets about both upper central incisors; transverse fracture of the left upper incisor.

about the tooth, which represents the peridental membrane. As the infection continues and the alveolar process becomes involved, the bone retracts from the neck and finally the roots of the teeth, which are then kept in place only by the fibrous tissue of the gums. As a general rule, when the retraction of the alveolar process involves over half of the root the tooth is doomed.

Alveolar Abscess.—Alveolar abscess in the acute stage, like osteomyelitis, gives no roentgen evidence of its presence. Very shortly, however, rarefaction appears about the root involved and at first the resulting dark area merges into the structure of the surrounding cancellous bone. As the process becomes more chronic, a limiting wall appears about it and the picture then becomes one of a definite dark sac attached usually about the apex of the root. This is the familiar form of alveolar abscess. Pathologically most of them are

FIG. 71.—Impacted upper canine tooth lying beneath a bridge.

found to be a mass of granulation tissue containing a certain number of bacteria, less frequently a definite abscess cavity with a lining membrane. Erosion of the tip of the root extending into this cavity is often seen and in long-standing cases deposits of new bone laid down about the apex of the root produce bulbous enlargements and may wholly or in part fill the old abscess cavity. The treatment of such an abscess is one to be decided by all the other evidence, medical and dental, which can be acquired. Not every tooth which shows an alveolar abscess should be extracted. Each case should be treated upon its individual merits. Abscesses must not be confused with extensions of the antra downward or pockets in the antra in the region of the upper bicuspids and molars nor with the submental foramen which frequently overlies the apex of a lower bicuspid. Films of the upper incisors occasionally show the shadow of the nostril overlying a root which simulates an abscess.

Cysts.—Cysts are fairly common in the jaw. There are two forms: root cyst and dentigerous cyst. The former arises perhaps most

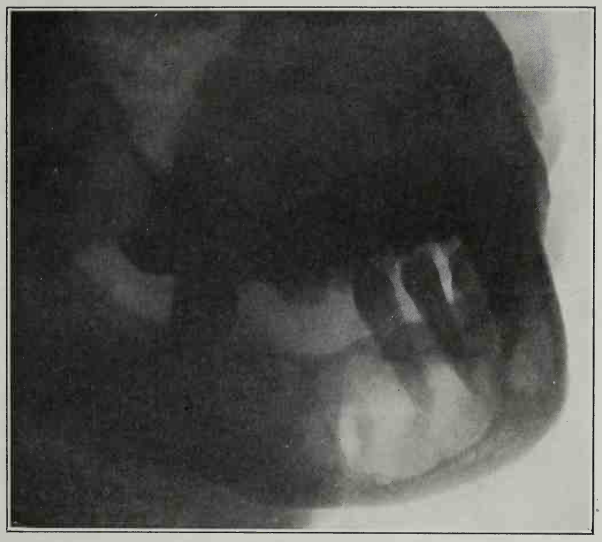

FIG. 72.—Simple cyst of the jaw.

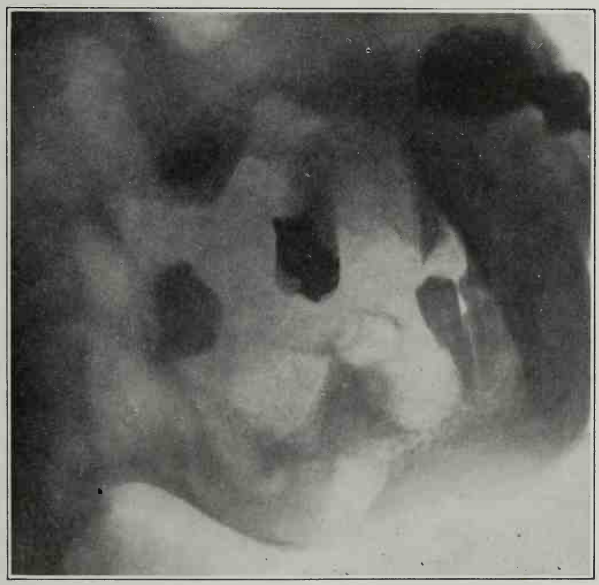

FIG. 73.—Dentigerous cyst.

frequently from an old alveolar abscess. It appears as a large rounded area of rarefaction in the jaw, usually attached to or partially enclosing one or more tooth roots and showing little or no evidence of trabeculation. They may be multiple. Dentigerous cysts have a similar appearance except that they develop from a buried tooth bud and generally contain teeth or portions of them. The bony structure of the jaws may be subject to any of the diseases which affect the rest of the skeleton. Osteomyelitis is fairly common and shows the same irregular destruction and proliferation seen elsewhere. A particular sort of osteomyelitis occurs with phosphorus poisoning; the bone becomes increased in density and

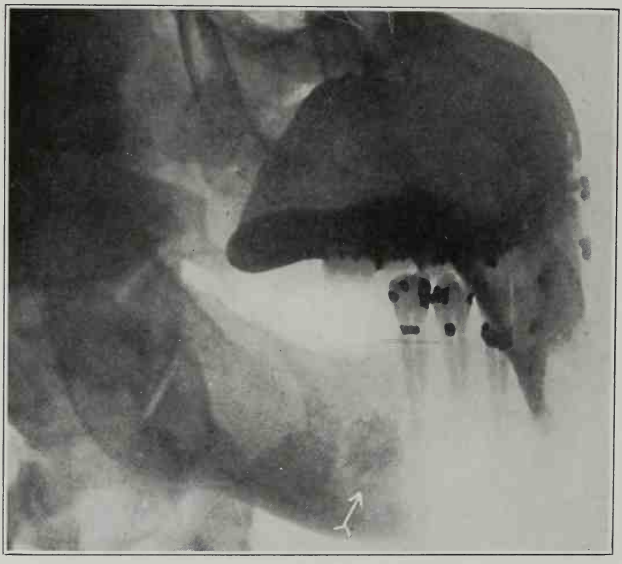

FIG. 74.—Cystoma of the jaw.

thickness as a result of new bone production which is followed later by suppuration and necrosis represented by irregular rarefaction. Syphilis occurs occasionally in the form of an irregular mottling of the bone due to extensive spotted rarefaction.

Tumors of all sorts may be encountered—giant-cell sarcoma and the more malignant forms of sarcoma, carcinoma and hypernephroma, for example. Their appearance is identical with that of similar growths in other flat bones. In addition, the jaw is the seat of a tumor peculiar to it, the odontoma, which is a dense mass made up of various tooth tissues and may be attached to a tooth or be com-

posed of several teeth fused together. Sometimes they take the form of undefined masses of considerable density, which continue to grow and develop into large deforming tumors.

Salivary calculi must be mentioned in any consideration of the teeth. They cast dense round or oval shadows seen in the position of the salivary glands or ducts. When projected upon the mandible in oblique views they must not be mistaken for areas of density in the bone. The shadows of calcified glands often appear in tooth plates. They are spotted mulberry-like shadows, characteristic of calcified glands anywhere. The tip of an unusually long styloid process may be projected upon the upper molar region and be mistaken for an extra tooth root or supernumerary tooth.

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CHAPTER VI.

JOINTS, TENDONS AND BURSÆ.

THERE is as yet no really satisfactory classification of the joint diseases because of the lack of accurate pathological knowledge. Probably the best one so far proposed is that of Barker, upon which the following outline is based. It must be insisted that no hard-and-fast adherence to the general types described below is possible. Atypical joints and those which fall under more than one heading are often observed. In the study of a pathological joint, the following features should be carefully noted: (1) Periarticular swelling in the soft parts, (2) effusion in the joint, (3) erosion of cartilage as evidenced by diminution of the joint space, (4) changes in density of the bone, (5) outgrowths of new bone formation and (6) the joints involved.

Hypertrophic arthritis is the most common form. It occurs in individuals over forty, more often men. Its characteristic feature is the presence of spurs or lipping on the margins of articular surfaces, which include vertebral bodies. These outgrowths are dense with sharp edges and in some cases cause fixation of a joint by interlocking or fusion. There is no fluid in the joint unless it has been recently injured. There is usually no loss of articular cartilage and no decalcification of adjacent bone. It may attack any joint, usually the larger, and is very common in the spine. These joints may exist for a considerable length of time without giving many symptoms but they are apparently points of lowered resistance, for after injury they may be the seat of acute painful reactions which are entirely out of proportion to the injury and would not have occurred in a normal joint. This condition is continually being encountered in industrial accident work.

Gout.—Gout is less common but, like the first type, occurs after forty, more frequently in men than in women. In a typical case it presents periarticular swelling and very characteristic punched-out areas in the bones at the margins of the articular surfaces. These holes are sharply cut and vary from one to several millimeters in diameter, in severe cases causing complete destruction of an articular

end of the bone. There is little effusion in the joint, erosion of the cartilages occurs only in the late severe cases and there is no decalcification. Usually some slight hypertrophic spurs are present. It ordinarily occurs in the phalangeal joints of the hands and feet, but may affect the carpus or tarsus and in rare cases a large joint, such as the knee, simulating here an early Charcot joint from the amount of destruction and new bone formation which takes place.

FIG. 75.—Gout.

In the early stages before the punched-out areas become evident it may be mistaken for a hypertrophic arthritis. It is, of course, accompanied by other clinical evidence of the disease.

Charcot Joints.—A striking picture which occurs in patients with tabes or syringomyelia is seen usually in middle age. There is tremendous swelling of the soft parts, destruction of articular surfaces, amounting to complete disorganization, and large irregular masses

of calcified material scattered throughout the joint. There is no decalcification of bone. Its commonest sites are the knee, hip, ankle and spine. Conditions which may be confused with it are (1) gout, which is rare in large joints and always involves the smaller ones in addition; (2) loose bodies in joints, in which case the calcified masses are small, dense and few in number, and the joint surfaces are not disturbed except that the point of origin of the

FIG. 76.—Charcot joint.

fragment may be evident in a chipped-off area on the inner condyle of the femur; or (3) calcified hematomata, in which the calcification is much more extensive and the joint surfaces are intact.

Atrophic Arthritis.—Atrophic arthritis is more common in women and it is seen between the ages of twenty-five and forty-five. It begins with periarticular swelling followed by gradual loss of articular cartilage, shown by narrowing of the joint space and by

severe atrophy of the soft parts, and decalcification of bone. There is no tendency to new bone or spur formation. The hands and feet are usually affected first, and later, the knees, elbows, and shoulders may one or all be involved. The process extends over a period of years, ending typically in complete ankylosis.

Infectious Arthritis.—Infectious arthritis attacks any joint at any age. Its forms are extremely varied owing to the number of causative agents. The most common types are pyogenic, gonorrheal, tuberculous and syphilitic.

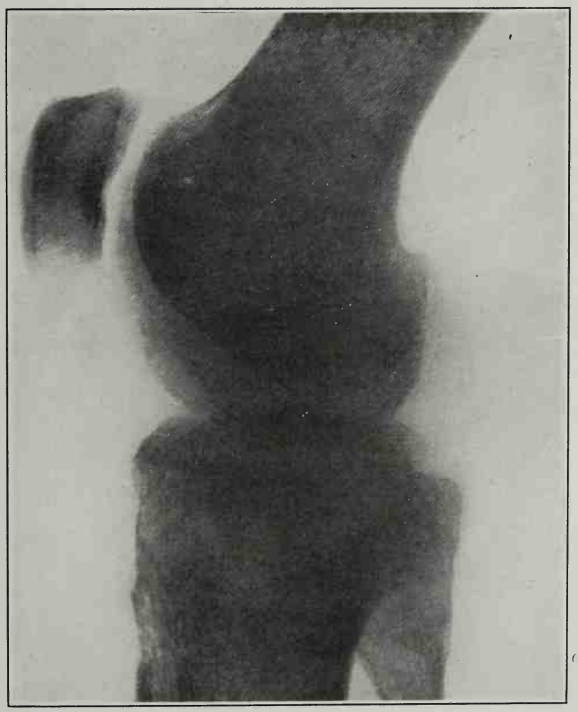

FIG. 77.—Infectious arthritis of the knee-joint. An early case.

Pyogenic Arthritis.—Pyogenic arthritis is usually due to staphylococcus, streptococcus or pneumococcus. The acute forms attack one or many joints which show soft tissue swelling and effusion in the synovial cavity. The process may then subside with disappearance of these signs. If it persists for several weeks, decalcification of the articular ends of the bones will occur and there may be erosion of cartilage with narrowing of the joint space. Later, as repair begins,

hypertrophic changes may make their appearance at the margins of the articular surfaces or the cartilage may be entirely destroyed and ankylosis result when healing is complete.

Gonorrheal Arthritis.—Gonorrheal arthritis is usually monarticular but it may be indistinguishable roentgenologically from other pyogenic infections. However, there are two findings in addition to those of pyogenic infection which are very suggestive of Neisserian origin. One is a localized destruction of the cartilage on the under surface of the patella which sinks in toward the condyles of the

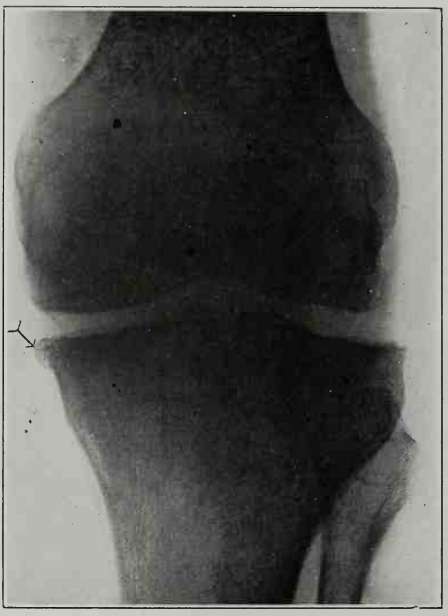

FIG. 78.—Hypertrophic arthritis of the knee-joint.

femur. Subsequently hypertrophic changes appear on its margins and on the adjacent areas of the femur. The second is the occurrence of small localized areas of rarefaction in the bone at the junction of articular surfaces and cortex. Another result of this infection is the development of new bone deposits along tendinous attachments. These spurs may be the result of the activity of other cocci, but the great majority are gonorrheal.

Tuberculosis.—Tuberculosis is more common in children. It causes slight enlargement of the soft parts, effusion in the capsule, and general haziness and muddiness of the entire joint area. There

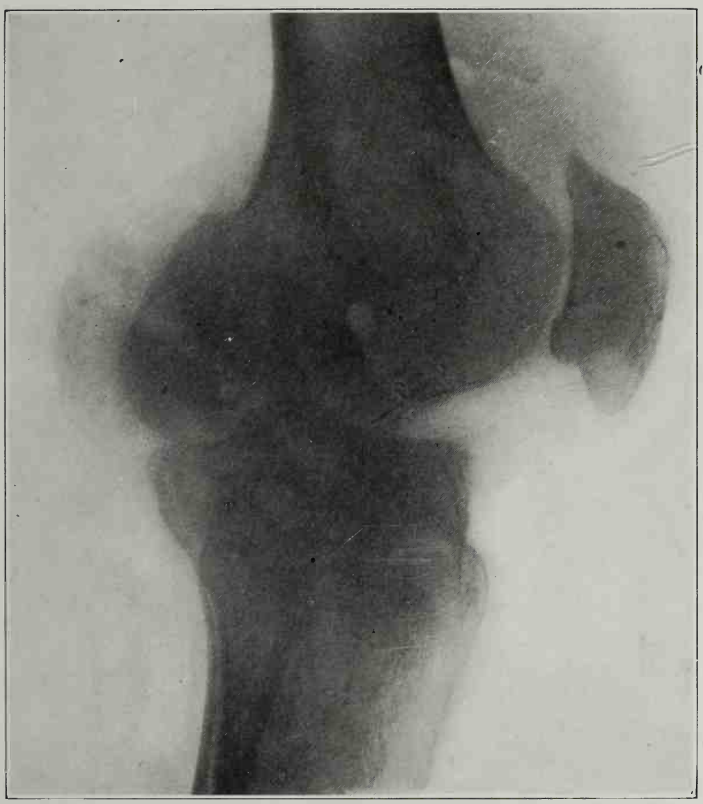

FIG. 79.—Tuberculosis of the knee-joint.

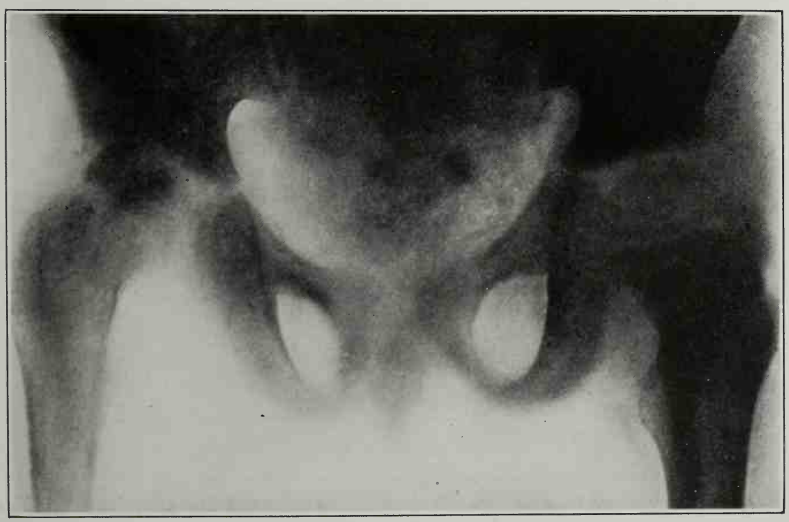

FIG. 80.—Tuberculosis of the hip. An early case.

FIG. 81.—The same case as Fig. 80, two years later. The process is now well advanced and quite typical.

FIG. 82.—The same case as Fig. 80, three years after the first examination. The disease is now arrested.

is extreme decalcification so that the outlines of the bones may be reduced to a thin pencilled white line. Enlargement and squaring of the epiphyses are seen and later more or less destruction of joint surfaces, and interference with the growth of the bone. There is no new bone formation. The occurrence of periosteal reaction and bony ankylosis in these joints is generally the result of secondary infection. During the process of repair there is increase in density due to deposit of lime salts. Caries sicca is seen most commonly in the shoulders in adults. It shows a chronic ragged erosion of the articular surfaces, no soft tissue swelling, no effusion and no decalcification. (Fig. 35.) Occasionally small foci occur in the epiphyses, appearing as localized areas of decreased density, with little or no evidence of joint involvement.

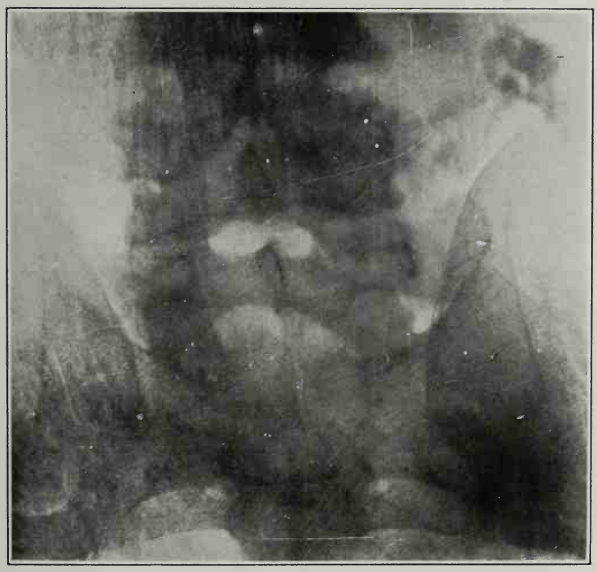

FIG. 83.—Gumma of the spine.

Syphilis.—Syphilis may be seen at any age and it is manifested by increased density in the soft tissues and the occurrence of a slight periostitis at the junction of the periosteum and synovial membrane; occasionally by destruction of articular surfaces, particularly those of the small bones, such as carpus and tarsus, and by local lesions in the epiphyses suggesting tuberculous foci. In some cases, as the result of chronic low-grade inflammation in the synovial membrane, low, rounded hypertrophic ridges will appear at the margins of the articular surfaces.

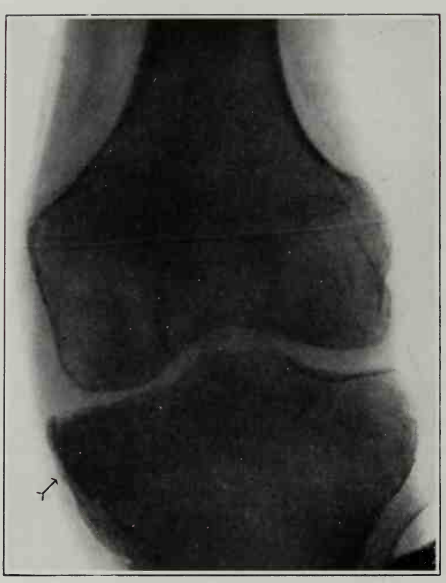

FIG. 84.—Syphilis of the knee-joint.

FIG. 85.—Multiple calcified bodies in the knee-joint.

Villous Arthritis.—Villous arthritis consists of a thickening in the soft parts due to overgrowth of synovial fringes. It may be seen in lateral views of the knee, where the posterior portion of the capsule is occupied by a mass of slightly greater density that normal, and where a stringy, fan-shaped shadow can be made out radiating anteriorly between the condyles of the femur and tibia.

Hemophilia.—When the joints are involved in this disease the signs are those of chronic joint irritation suggesting tuberculosis. There is bone atrophy amounting even to pencilling of the outlines, effusion into the joint and moderate enlargement and squaring of the epiphyses. At times erosion of the articular ends of the bones may occur, or calcification of the blood-clot within the joint.

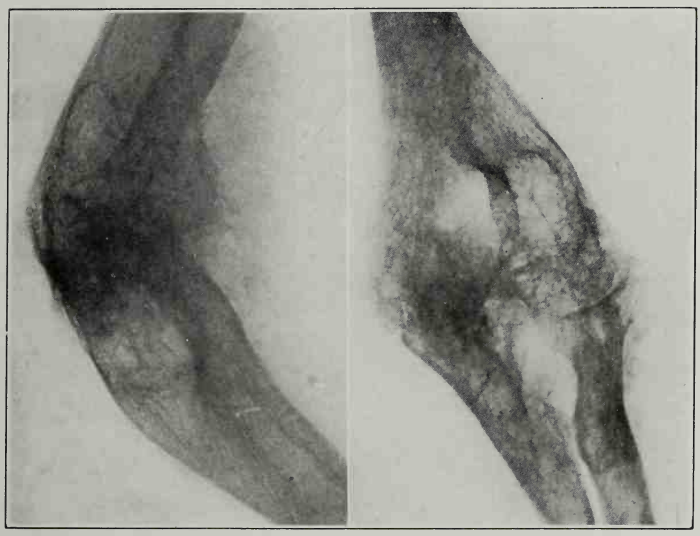

FIG. 86.—Hemophilia with organizing blood-clot in the capsule of the elbow-joint.

Osteochondritis Desiccans.—Osteochondritis desiccans is characterized by the presence of a mass of cartilage loose in the joint whose site of detachment may usually be made out upon the articular surface of the inner condyle of the femur. If these loose pieces do not calcify they are invisible, but fortunately most of them become calcified in the course of time. Loose fragments of semilunar cartilages become similarly calcified. In the early stage of the condition, before calcification has occurred, it is difficult or impossible to visualize the fragment. The injection of oxygen gas into the joint may clear up the diagnosis.

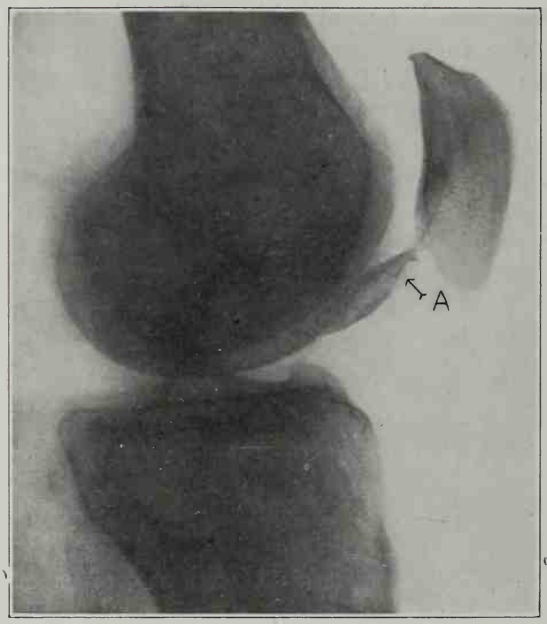

FIG. 87.—Osteochondritis desiccans. Calcified loose mass of cartilage at *A*.

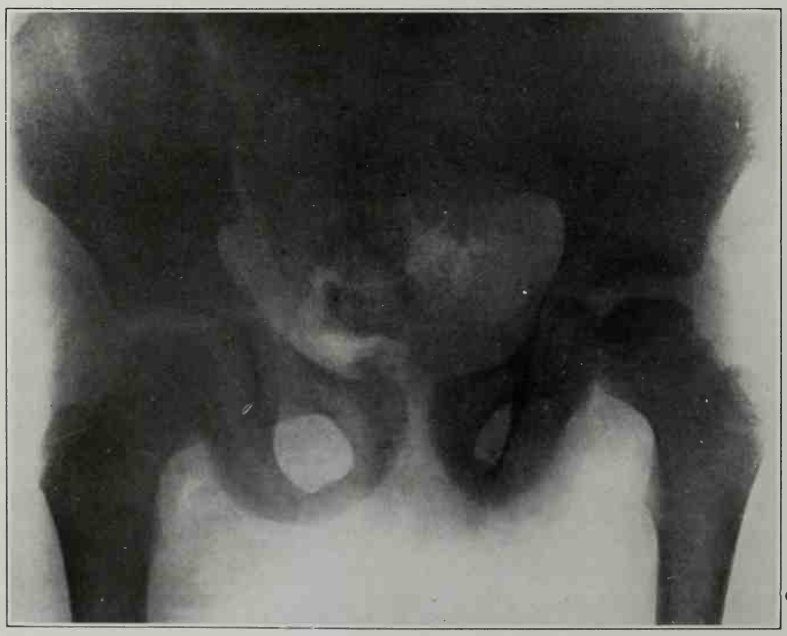

FIG. 88.—Perthe's disease. An early case. Note the slight deformity of the head of the femur.

FIG. 89.—Perthe's disease. The same case as Fig. 88, one year later. The process is now well marked and quite typical.

FIG. 90.—Perthe's disease. Same case as Fig. 88, three years after the first examination. The head of the femur is more dense, showing that repair is taking place.

Osteochondritis Deformans (Legg's or Perthe's disease).—Osteochondritis deformans is revealed by a flattening and mushrooming of the head of the femur, suggesting tuberculosis but without typical clinical signs. The joint is not involved. There is little bone atrophy

FIG. 91.—Myostitis ossificans. Note the bone formation in the soft tissues about the knee.

and interference with growth is not marked. It is possibly due to interference with the blood supply of the epiphysis. The end-result of such a process as seen in adults is a flattening of the head, which is sometimes displaced downward slightly on the neck.

TENDONS AND BURSÆ.

Effusion or hemorrhage in or about these tissues is shown by an area of slightly increased density with indefinite margins. Synovitis of the Achilles, quadriceps or extensor longus pollicis tendons may occasionally be suspected from thickening of the shadow and blurring of its ordinarily sharp outlines.

Calcification is frequently encountered at tendinous attachments particularly those of the triceps on the olecranon, the quadriceps and patellæ tendons on the patella and the Achilles and plantar tendons on the os calcis. The great majority of these lesions are gonorrheal although other cocci may be responsible for them at times.

Areas of increased density seen in the region of the subdeltoid bursa may be true calcifications in the bursa, which are rare; accumulations of an opaque gelatinous substance in the bursa; or, what is more common, calcification about the tendon of the supraspinatus beneath it. Calcification may occur in any bursa which has been the seat of trauma or infection.

Myostitis Ossificans.—A rare disease in which ossification occurs in the soft tissues. There are two forms, one following trauma and the other congenital, of no known etiology, following a very slowly progressive course. In both cases there is hemorrhage into the soft parts and instead of the normal absorption, a more or less complete ossification. The first form is prone to occur about joints after dislocations and in muscles subject to trauma such as the quadriceps. The disease is to be differentiated from calcification extending into the soft tissues as a result of periosteal injury and other outgrowths which arise from the bone.

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CHAPTER VII.

THE CHEST.

The shadow of the chest may be divided into (1) that of the thoracic wall, (2) a central shadow consisting of supraposed sternum, heart, great vessels, mediastinum and spine, (3) the diaphragm and (4) the lung fields.

Pathological processes in the thoracic wall may consist of injuries to the ribs, of infections and of tumors. They are similar to the same processes elsewhere. Occasionally there is an emphysema of the soft tissues usually associated with fracture of the ribs or surgical interference. The plate is very striking and shows the presence of dark areas representing air scattered through the muscles and subcutaneous tissue.

The central shadow is concerned with the outlines of the thymus and thyroid, of mediastinal masses and with the shape, size and position of the shadows of the great vessels and pericardium. Normally the thyroid and thymus are not visible in a chest plate. A substernal thyroid or enlarged thymus appears as a dilatation of the upper end of the central shadow with sharp margins which extend upward beyond the clavicles. In children, an enlarged thymus gives a particularly characteristic shadow. It is roughly quadrangular with rounded lower corners and sharp margins which extend straight down from above the clavicles and overlap the shadow of the heart and vessels. It is less dense than other tumors and is easily overlooked. In our experience, lateral and oblique views are of little value in its recognition.

The thyroid, when intrathoracic, shows as a dense, sharply defined shadow extending down and overlapping the great vessels. It may be differentiated from thymus and other mediastinal tumors by the fact that it moves with deglutition.

Mediastinal masses may be due to enlargement of the mediastinal glands, growths, aneurysms, vertebral abscesses and dilatations of the esophagus.

Enlargement of the glands is usually due to tuberculosis, Hodgkin's disease or malignancy. Their outline is sharp and irregular

or lobulated and the process is usually bilateral. They seldom show pulsation although large masses may transmit the impulse of heart or aorta. By careful fluoroscopic examination it is sometimes possible to separate their shadow from that of the aorta or to demonstrate a normal aorta.

The most common tumors are lymphosarcoma, Hodgkin's disease, and carcinoma, primary or metastatic. They produce dense shadows with sharply defined borders and may displace or compress the surrounding organs, often showing transmitted pul-

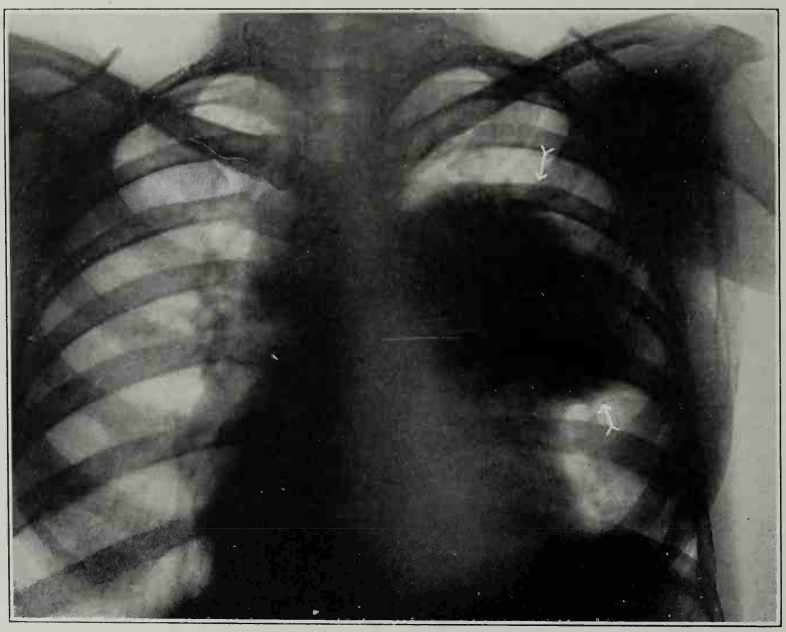

FIG. 92.—Malignant tumor of the mediastinum, resembling aneurysm.

sation. They may be mistaken for aneurysm, but careful study with the fluoroscope and plates at different angles will usually differentiate them. In lymphosarcoma and Hodgkin's disease, glands elsewhere in the body are usually involved and the masses temporarily disappear with great rapidity under roentgen radiation. Primary malignancy is rare. It usually occurs as a unilateral, irregular enlargement of the hilus shadow which shows a tendency to grow in the direction of the affected bronchi. Metastatic malignancy, in addition to the enlargement of the hilus shadows, may

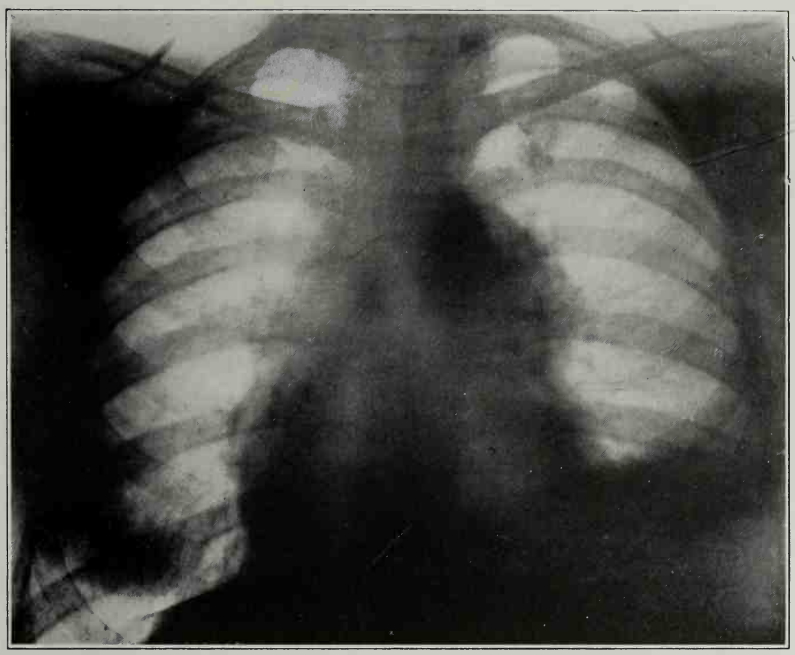

FIG. 93.—The same case as Fig. 92. After a series of treatments with *x*-rays the decrease in the size of the tumor rules out aneurysm.

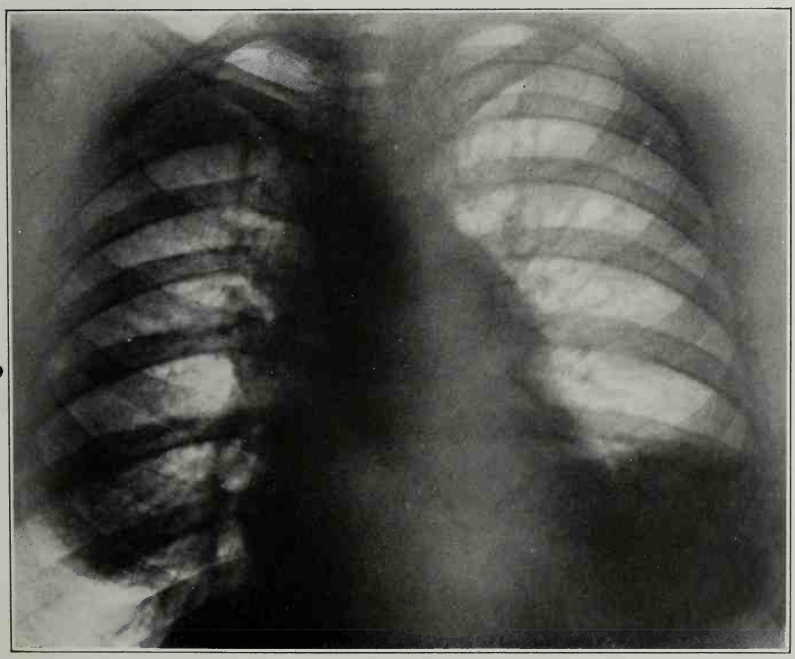

FIG. 94.—The same case as Fig. 92, one year after the first examination.

show the characteristic, annular, sharply defined patches through the lung fields. Teratomata may invade the mediastinum in rare cases, causing an increase in the width of the central shadow without distinguishing characteristics. Dermoid cysts may occur and should be recognized by their cystic wall and the fact that they arise from the mediastinum. Endotheliomata and lipomata may also develop in this region.

THE HEART AND GREAT VESSELS.

In an examination of the heart we should obtain the following data: Size, shape, its movements with respiration, pulsation of the

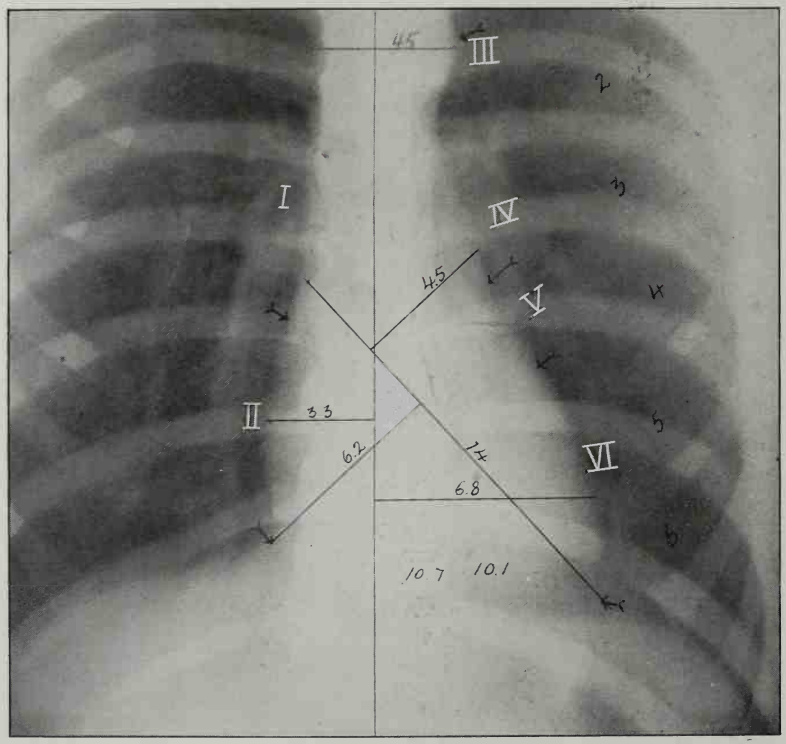

FIG. 95.—Teleradiagram of the normal heart and great vessels: *I* on the right is the ascending aorta; *II* on the right is the right auricle; *III* on the left is the aortic arch; *IV* on the left is the pulmonary artery; *V* on the left is the left auricle; *VI* on the left is the left ventricle.

various chambers, and any change of shape which may occur with change in position of the patient. We should also note the size

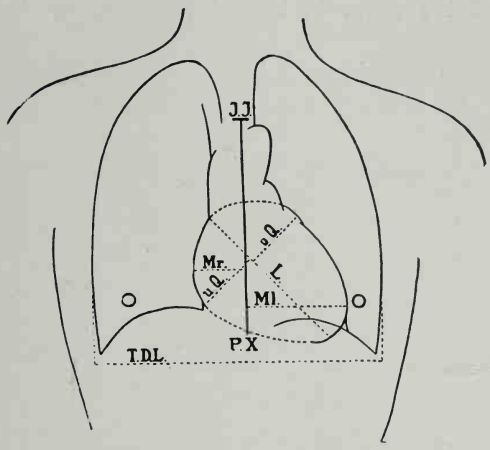

FIG. 96.—Tracing showing the shape of the normal heart and great vessels and the points from which measurements are taken. (From Groedel.)

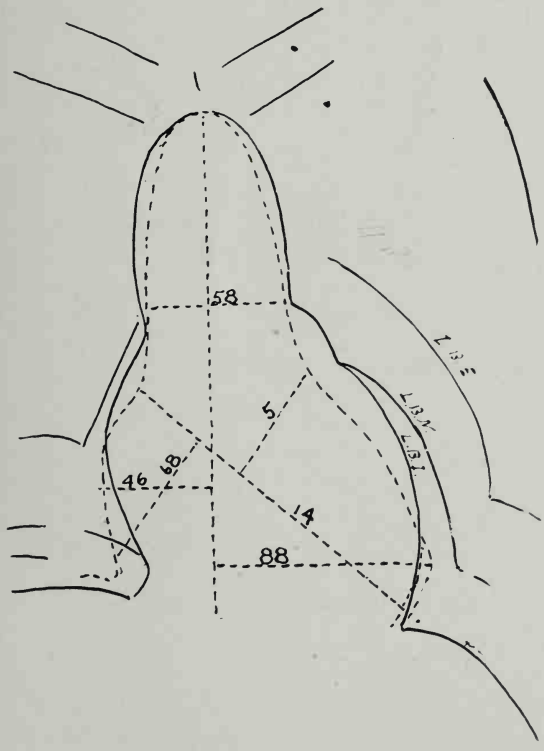

FIG. 97.—A tracing showing the normal respiratory excursion of the heart and diaphragm during quiet and forced breathing. Patient is standing.

and shape of the aorta in both its anteroposterior and lateral diameters.

This data may be obtained by means of orthodiagraphy or by combination of teleroentgenography and fluoroscopic examination.

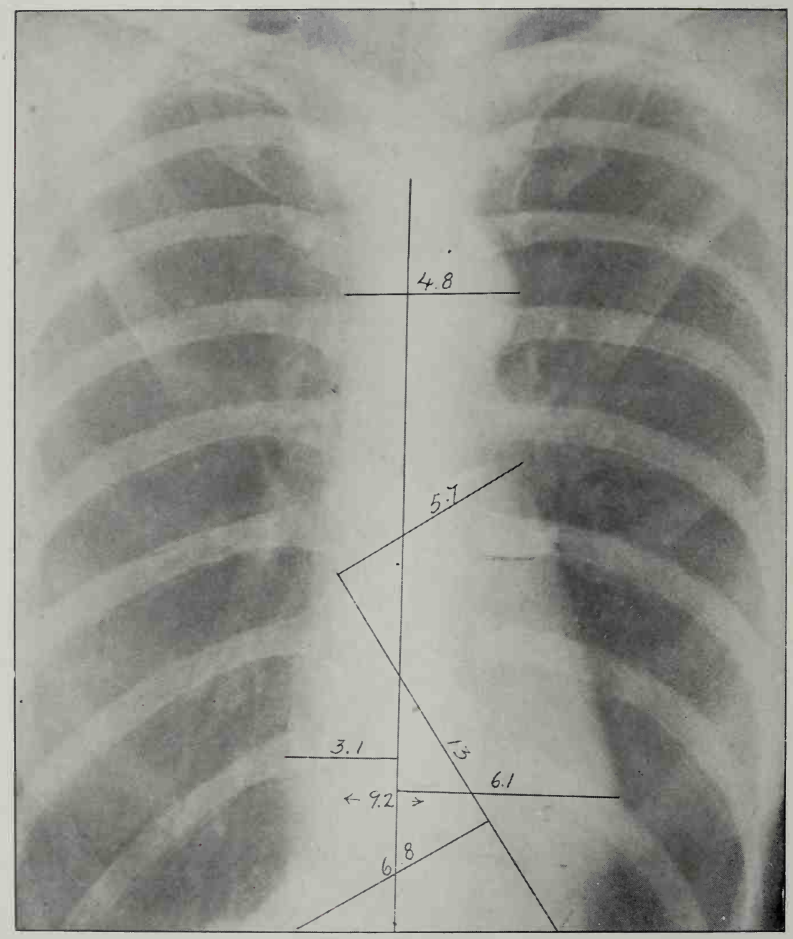

FIG. 98.—The drop heart of the ptotic.

The advantages of orthodiagraphy are its accuracy in the hands of experts and ability to outline the apex. Its disadvantages are: the time required to perfect a technic, and constant chance for error due to the personal limitations of the operator.

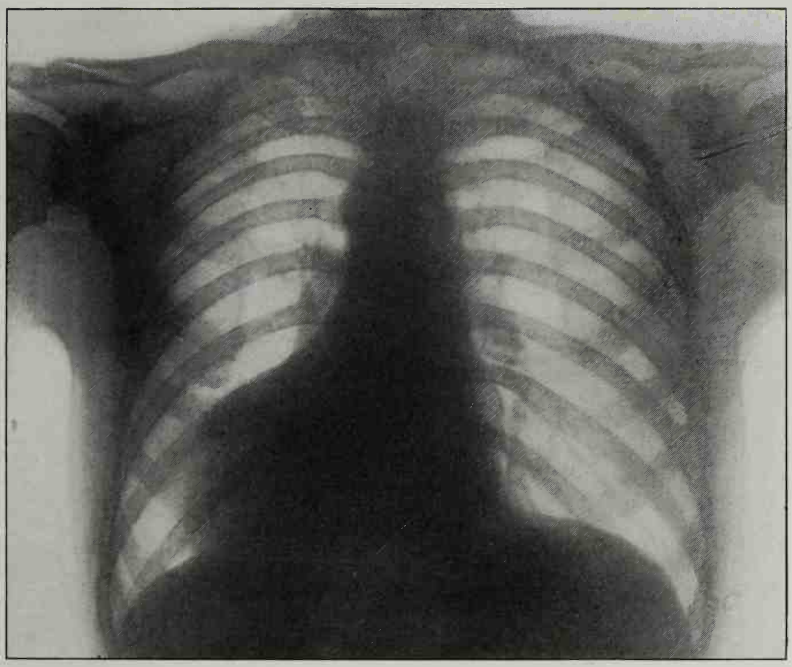

FIG. 99.—The enlargement of the left ventricle in aortic regurgitation.

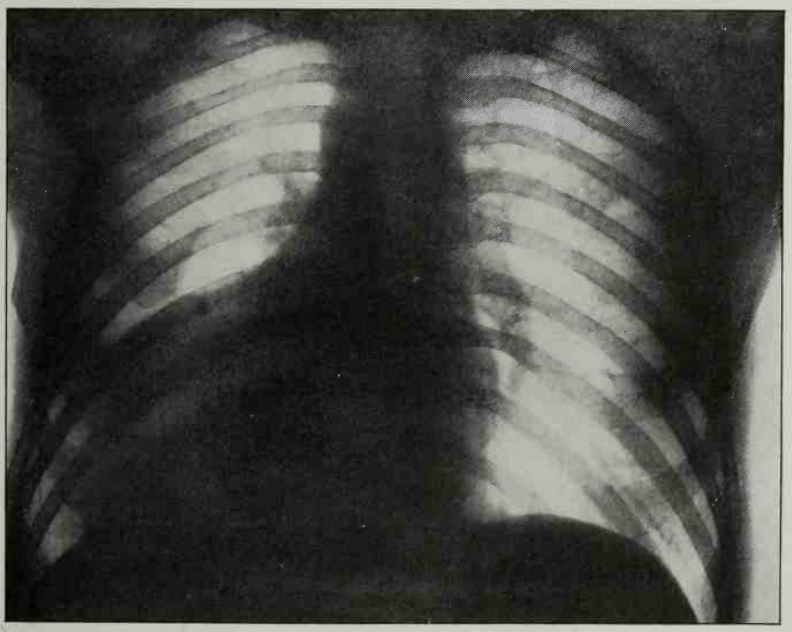

FIG. 100.—The same case as Fig. 99, but taken at two instead of six feet, Note the distortion of the enlarged left ventricle.

Teleroentgenography has the advantage of eliminating the personal equation and of producing a permanent record. Its disadvantages are: the slightly higher cost and the difficulty of demonstrating the apex and the junction of the left auricle with the left ventricle. These points are of importance, as without them all the measurements cannot be obtained.

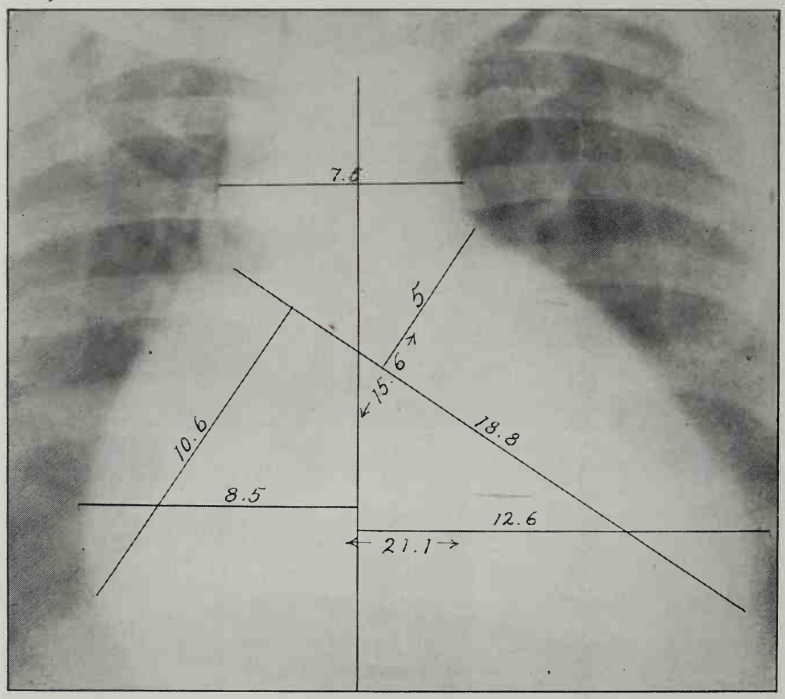

FIG. 101.—The dilated heart.

By fluoroscopy it is possible to obtain a fairly accurate outline of the shape and position of the heart shadow and of its movements with respiration; also of any change of shape which may occur with change of position. By combining this data with the data obtained from a plate taken at a seven-foot target film distance, all the required findings are present.

This method of combined fluoroscopy and teleroentgenography has been in use at the Massachusetts General Hospital for the past eight years and has proved quite satisfactory. The fluoroscopic observation is made first. The patient is placed in the upright posi-

tion behind a fixed screen. The focal spot of the tube is at a distance of 24 inches from the screen. From 2 to 3 ma. at 60,000 volts gives a good image.

A thin plate of glass in front of the fluoroscopic screen serves as a receptacle for the tracing which is made of the outline of the heart and great vessels during normal breathing, forced inspiration and forced expiration.

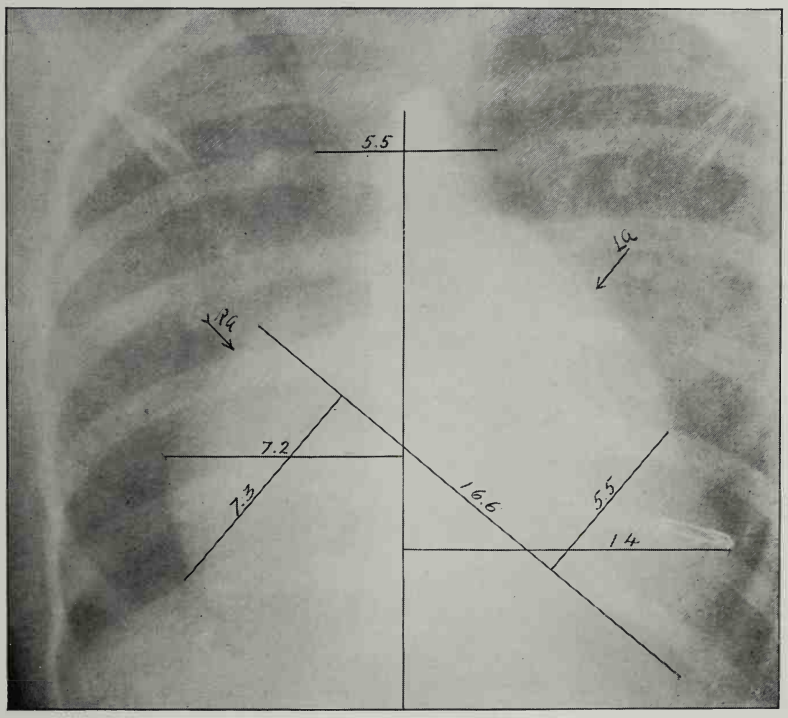

FIG. 102.—Mitral disease.

The patient is then rotated to the left so that his right chest is in contact with the screen, and the posterior mediastinal space with the arch of the aorta are studied. By changing the position of the patient slightly, the size of the shadow of the aorta will be seen to grow larger or smaller. The smallest possible shadow which can be obtained represents the true diameter of the aorta plus the amount of magnification due to its distance from the screen.

A tracing is made of the aorta in this position for comparison

with the tracing made in the anteroposterior view. From the two tracings an estimate can be made of the amount of overlapping of the ascending and descending aorta. The glass with its tracing is removed and the pulsation of the various chambers of the heart is studied and compared. If there is anything in the findings which suggests a pericardial effusion, the patient is examined in the prone position.

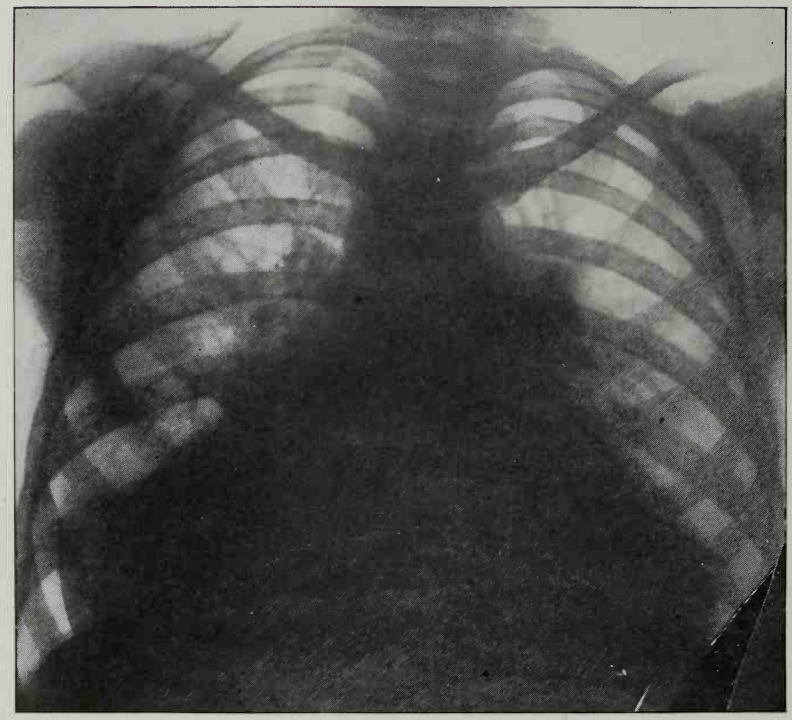

FIG. 103.—The water-bottle shape of the heart shadow seen in pericardial effusion with the patient upright.

After the fluoroscopic observations are completed, a mark is placed on the patient's chest opposite the center of the heart shadow to serve as a point upon which to focus the tube for the plate which is taken with the patient standing. The focal spot of the tube should be at a distance of at least six feet from the plate.

Special care must be taken so to place the patient that the central rays from the tube pass through the chest at right angles to its

transverse diameter. At this distance a small amount of displacement of the tube to the right or the left from the median line does not appreciably distort the heart shadow, but a slight rotation of the patient does produce definite distortion.

In stout patients it is better to have the plate in contact with the chest wall and the patient standing erect. If the plate is placed at

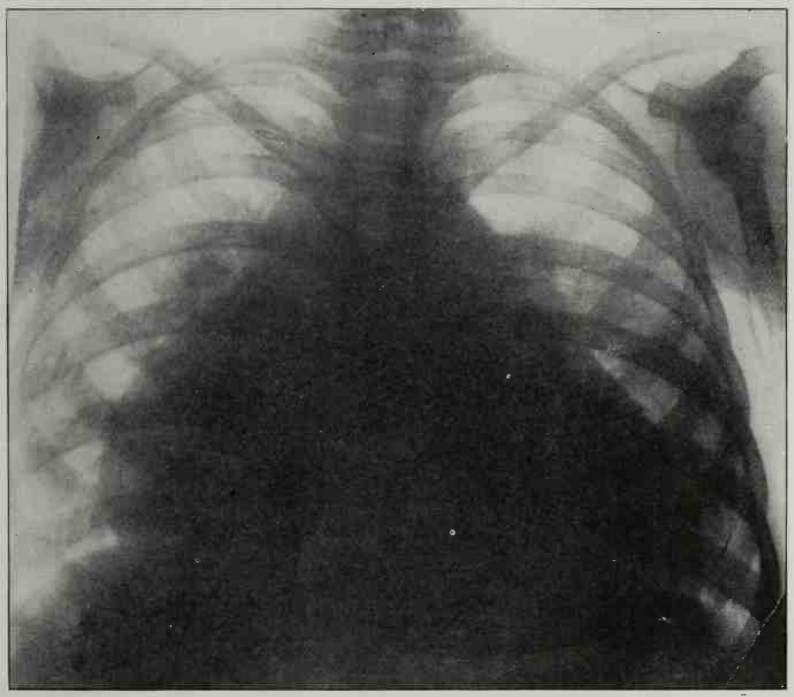

FIG. 104.—The same case as Fig. 103, but taken with the patient prone. Note the change in the shape of the heart shadow, due to the shifting of the fluid within the pericardium.

right angles to the central ray from the tube, its upper portion may be some distance from the chest wall, and as we are not dealing with absolutely parallel rays, a slight amount of magnification of the aorta will result.

On the other hand, if the patient is allowed to lean forward to bring the chest entirely in contact with the plate, there will be a certain amount of apparent sagging of the contents of the chest.

The time of exposure should be sufficiently long to cover one full

heart cycle, so that the shadow obtained will be the shadow of the heart in diastole. Where very rapid exposures are made the resulting picture may represent the heart either in systole or diastole or at some phase between. The period of diastole is the one from which estimates of the heart size are made.

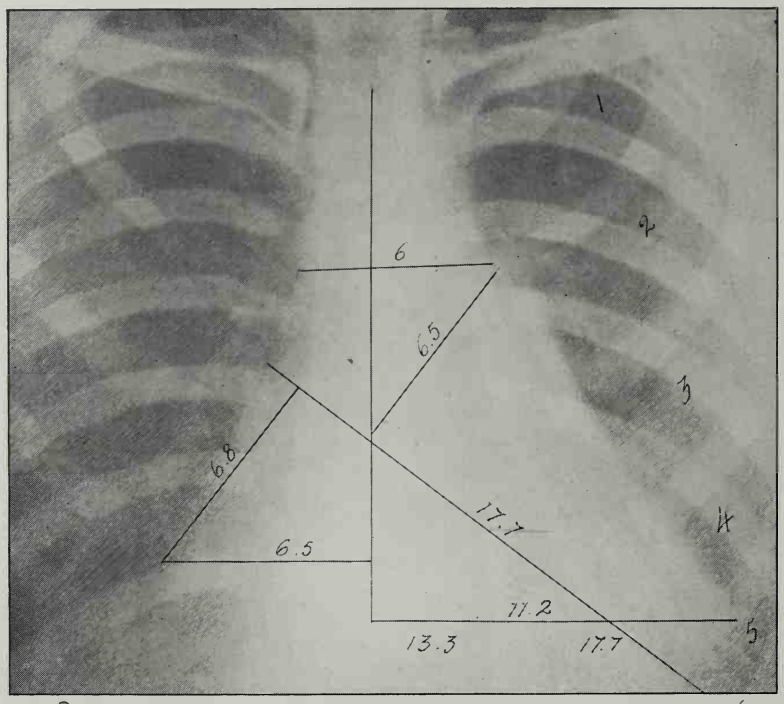

FIG. 105.—The triangular shape and indefinite outline of the heart seen in adhesive pericarditis.

Therefore, it is evident that a relatively long exposure is desirable. The patient should be instructed to keep still, but it is not desirable for him to take a deep breath nor is it necessary to hold the breath. The amount of movement of the heart shadows in normal respiration is very slight. With deep inspiration there is a definite change both in the shape and size. The amount of current passed through the tube may vary according to the type of apparatus available. About the same degree of penetration should be used as in frontal sinus work. Intensifying screens are desirable.

After the plates are developed and dried the measurements are made from them according to the plan adopted by Groedel. This

plan includes six points from which measurements are taken: three on the right and three on the left side of the heart shadow. The upper point on the right is at the junction of the heart shadow with that of the great vessels. The second point on the right is at the furthest point of the heart shadow to the right, and the lowest point is at the junction of the heart shadow with the diaphragm. On the left, the highest point is at the junction of the left auricle with the left ventricle. The second point is at the greatest distance to the left, and the third point is at the heart apex. A line is then drawn along the center of the spinal column. This may be used as the midline.

The greatest distance to the right and the greatest distance to the left from this line are easily obtained. Their sum represents the greatest transverse diameter of the heart shadow. A line drawn from the highest point on the right to the heart apex represents the total length of the heart; and lines drawn at right angles to it, one to the highest point on the left and one to the lowest point on the right, give us the diameter of the base.

By comparing these figures with the internal diameter of the chest, and the shape of the heart and aorta the respiratory movements and pulsations as recorded on the tracings the conclusions are made.

To interpret the findings one must have a thorough knowledge of the anatomy of the heart and great vessels, and of the normal radiographic shadow.

Normally, the central shadow approximates the outline in Fig. 95. At the top, on the left side, the edge of the arch of the aorta appears with the descending aorta extending downward from it; below it the slight prominence of the pulmonary artery and the small left auricular appendage in the angle between it and the ventricle. The rounded mass of the ventricle makes up the largest part of the shadow and disappears below the diaphragm line. The location of the apex is a matter of considerable uncertainty, as it varies with the size, shape and position of the heart and of the patient, and the position and shape of the diaphragm.

The right border begins at the top with the poorly defined shadow of the superior vena cava above and overlapping the ascending aorta, which is sometimes indented by the right bronchus in its lower portion. The line then curves outward over the right auricle to join the right diaphragm at an acute angle at the apex of which the inferior vena cava is sometimes apparent.

The right ventricle is not visible in the anteroposterior view as its shadow is superimposed upon that of the left ventricle and auricles.

The Normal Heart.—The shadow of the heart is subject to all the laws governing the shape and size of the shadow of any objects, and to variations due to changes in the position of the heart within the thoracic cavity, in addition to those conditions which actually change the shape or size of the normal or pathological heart. For this reason comparison of the area or size of the shadow of any given heart with those made from the organ itself are often misleading and useless. Comparison should be made only with the shadow of normal hearts obtained under similar conditions, and no attempt to state the actual size of the heart should be made. The figures given are the size of the shadow produced—not of the heart, and have the same value in diagnosis as those obtained by the most accurate methods of percussion.

The following are some of the non-pathological conditions which may change the shape or size of the heart silhouette: age—in youth the heart hangs more vertical in the thorax than in old age when its long axis tends toward the horizontal. Consequently its shadow is more round and its transverse diameter relatively diminished.

With a high position of the diaphragm the apex is raised and to some extent the entire heart, and its shadow is increased principally in its transverse diameter.

The height, weight, sex, the size and shape of the thorax, also influence the size and shape of the heart.

Heart Measurements.—The following table worked out by Claytor and Merrill[1] gives a fairly good guide as to the measurements of the normal heart.

Males (37 cases).

Weight, pounds.	Cases.	Mr.	Ml.	T. D.	L. D.	
		3.0	7.0	10.7	11.8	Minimum
120–129	3	3.7	7.2	10.9	12.6	Average
		4.3	7.5	11.3	13.5	Maximum
		3.5	7.5	11.0	12.0	Minimum
130–139	5	3.8	8.0	11.8	13.2	Average
		4.2	8.5	12.5	14.0	Maximum
		3.4	7.0	11.0	12.0	Minimum
140–149	9	4.0	7.7	11.9	13.4	Average
		4.6	8.4	13.1	14.5	Maximum
		3.2	7.8	11.5	12.5	Minimum
150–159	8	3.9	8.4	12.3	13.5	Average
		4.5	9.0	13.0	15.0	Maximum
		3.7	8.0	12.0	14.0	Minimum
160–179	6	4.0	8.2	12.4	14.6	Average
		4.8	9.0	13.8	15.8	Maximum
180–200	6	3.8	7.0	11.0	14.0	Minimum
		4.2	8.7	12.9	14.7	Average.
		4.5	9.7	13.4	15.3	Maximum

[1] Claytor and Merrill: Am. Jour. Med. Sc., 1909, New Series, cxxxviii, p. 554.

Females (51 cases).

Weight, pounds.	Cases.	Mr.	Ml.	T. D.	L. D.	
100–109	2	3.2	6.7	9.9	12.0	Minimum
		3.3	6.8	10.2	12.1	Average
		3.5	7.0	10.5	12.3	Maximum
110–119	3	3.0	7.0	10.0	11.5	Minimum
		3.1	7.6	10.7	11.9	Average
		3.2	8.0	11.1	12.4	Maximum
120–129	14	2.3	6.4	10.2	10.5	Minimum
		3.5	7.5	11.0	12.2	Average
		4.2	8.6	12.2	13.8	Maximum
130–139	19	3.0	6.4	9.6	11.2	Minimum
		3.4	7.8	11.2	12.4	Average
		4.0	8.8	12.6	13.3	Maximum
140–149	5	2.6	7.0	10.0	12.2	Minimum
		3.5	7.6	11.1	12.7	Average
		4.1	8.3	11.8	13.2	Maximum
150–159	7	3.1	7.6	10.9	12.3	Minimum
		3.6	8.0	11.6	12.9	Average
		4.8	9.3	12.8	14.2	Maximum
160–175	4	3.5	6.5	10.6	11.8	Minimum
		3.8	7.9	11.7	12.6	Average
		3.8	8.5	12.3	13.0	Mean
		4.1	9.0	12.8	13.2	Maximum

Disease of the Aortic Valve.—The shadow of the left border is more curved and the apex blunt. The measurements are increased downward and to the left. The heart usually lies more horizontally in the chest, and there is usually a prominence of the ascending portion of the aorta. In aortic regurgitation there is a marked exaggeration of the pulsation of the arch.

Mitral Disease.—The shadows of the auricles are prominent. The measurement is increased to the right. The shape of the heart shadow is more round, and if stenosis predominates there is marked prominence of the shadow in the region of the left auricle and pulmonary artery with only a slight general increase in the size. In regurgitation the increase to the right is marked, and this is usually accompanied by a general enlargement of the heart shadow.

Combined Valvular Lesions.—These lesions are usually seen as a marked increase in size. The shape will depend upon the predominant lesion.

Hypertrophy of the Heart Due to Renal Disease or other Causes of High Blood-pressure.—The enlargement of the heart shadow is almost wholly in the region of the left ventricle. The increase is downward and to the left, as in aortic regurgitation; but the downward increase is most marked and the apex is not as blunt. The pulse beat becomes prominent and there is generally a diffuse enlargement of the shadow of the great vessels.

Auricular Fibrillation.—Auricular fibrillation may be demonstrated by the tremendous enlargement of the shadow of the auricles and absence of visible pulsation in them. In certain of these cases the heart shadow seems to rock.

Heart Block.—In this condition, if the pulsation is not too rapid, it is possible to compare the beats of the auricle with those of the ventricle and determine their respective rates.

Dilatation.—Dilatation is seen as a general enlargement of the heart shadow with weak pulsation and an absence of the rounding of the apex seen in hypertrophy.

Congenital Abnormalities.—The only congenital abnormality which gives a characteristic picture in the *x*-ray findings is that of patent ductus arteriosus and even this may be confused with pulmonary stenosis. In these conditions there is a marked prominence of the shadow of the pulmonary artery which is seen just above that of the left auricle. With an open foramen the heart is enlarged to the right and the pulmonary artery may be seen to pulsate with the ventricles.

Pericardial Effusion.—With fluid in the pericardium the heart shadow tends to become more triangular in shape. When the patient is prone there is an increase in the width at the apex of the triangle, and when upright an increase at the base, or it may assume a water-bottle shape. The cardiohepatic angle is seldom obliterated although it may be so to percussion. Pulsation is considerably diminished or absent, and its character is changed, the beat of the ventricles cannot be distinguished from that of the auricles, the impulse being more or less general over the entire left border. In obtaining the shape of the heart in different positions for comparison, it is not wise to depend on screen observations alone. Either a careful tracing or plates taken at a distance of seven feet should be made and the outlines thus obtained superimposed. An amount of fluid up to 200 c.c. may be present in the pericardium without giving any radiographic evidence. Encapsulated fluid may be mistaken for an enlargement of one of the heart chambers. Usually the diagnosis is between fluid in the pericardium and dilated heart, and is made on the absence of change in shape with change in position of the patient. The heart itself is not visible unless air is present within the pericardium.

Adhesive Pericardium.—It has been noted in a small group of cases that the respiratory excursion of the heart is limited. There is also apt to be some haziness in outline of the heart shadow and apparent obliteration of the angle between it and the diaphragm.

Dilatation of the Arch.—The dilatation of the aorta as seen radiographically occurs most frequently as the result of lues. There may be a considerable amount of dilatation present in arteriosclerosis and cases with high blood-pressure.

Very large hearts seem to have a relative enlargement of the aortic shadow. With a high position of the diaphragm the aortic shadow is slightly wider than in cases with a low diaphragm. Probably part of these variations are due to the difference in the shape of the aortic arch. In a wide arch there is less overlapping of the ascending and descending aorta and consequently an increased diameter of the shadow.

Specific aortitis tends to appear first above the aortic valves and as the wall of the aorta becomes weakened, a bulging of this area takes place. This appears as a variable prominence of the right border above the shadow of the auricle. A marked prominence of the aortic shadow to the right is almost always due to specific aortitis.

In arteriosclerosis the calcified plaques in the aorta are not visible unless extensive. The tortuous aorta, however, does give a definite, fairly characteristic change in the appearance of the aortic shadow. There is a distinct, sharp increase in the upper part of the shadow to the left with often the appearance of a knob at the junction of the transverse portion, and when viewed obliquely the tube will be seen to be of normal, or nearly normal, size. With long continued high blood-pressure there is probably in many cases a diffuse dilatation of the aorta present during life which cannot be differentiated from the diffuse luetic type by roentgen evidence alone, or a combination of two or more diseases may occur making the diagnosis difficult or impossible. In these cases the greatest help is obtained by a careful fluoroscopic study, comparing the oblique shadow with that of the anteroposterior view and noting the amount of expansion with each pulsation. Pulsation is diminished in arteriosclerosis; it is increased with high blood-pressure.

Aneurysm.—The size, position and location of aneurysms of the aorta are seen on the plate or fluoroscopic screen in sharp contrast to the surrounding lung structure. Should the lesion occur in the subclavian or vessels of the neck, which are not in contact with the lung structure, the aneurysm is invisible.

Aneurysms of the ascending aorta are seen to the right, while aneurysms of the arch usually show to the left of the spine high up.

Aneurysms of the descending aorta are seen in the lower portion of the aortic shadow to the left and they may be partially hidden by the shadow of the heart. Large diffuse aneurysms may appear as a general increase in the shadow of the great vessels.

The pulsations of aneurysms are not always seen on the fluoroscopic screen. It is extremely difficult to differentiate between expansile and transmitted pulsations, so that the presence or absence of pulsation, as observed fluoroscopically, is not of conclusive value in the diagnosis. The position of the sac is of more importance. Its

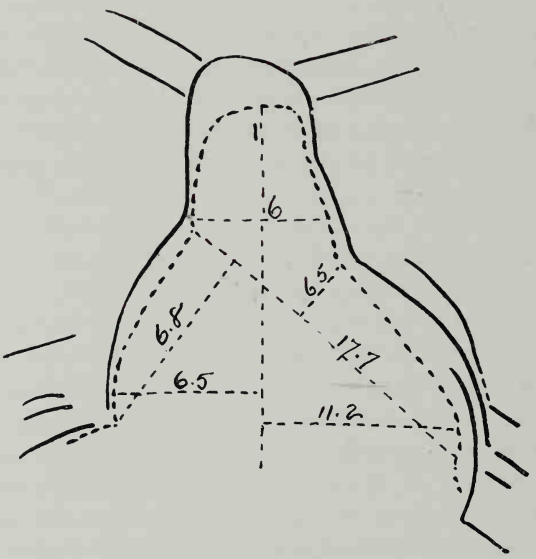

FIG. 106.—A tracing showing the limited respiratory movements of the heart in adhesive pericarditis.

outline should be sharply defined and the shadow of the normal aorta should not be seen through it. Mediastinal tumors other than aneurysms are usually less sharply defined. They may be nearer the front or back of the chest than the position of the great vessels, or they may occupy a position higher or lower than is usually occupied by aneurysms; and occasionally the shadow of a normal aorta may be seen through them. They are more likely to displace the heart and aorta than are aneurysms and do not in themselves cause enlargement of the heart which is a frequent accompaniment of aneurysm.

Perivertebral and Mediastinal Abscess.—Perivertebral abscess will usually give a more or less fusiform shadow appearing on both sides of the central shadow unless it occurs behind the heart. It may be confused with the shadow of the aorta. Inasmuch as it frequently results from a lesion in the spine, the recognition of a destructive process in the vertebræ is of considerable aid in the diagnosis. Lateral views are of great help as they show the bodies

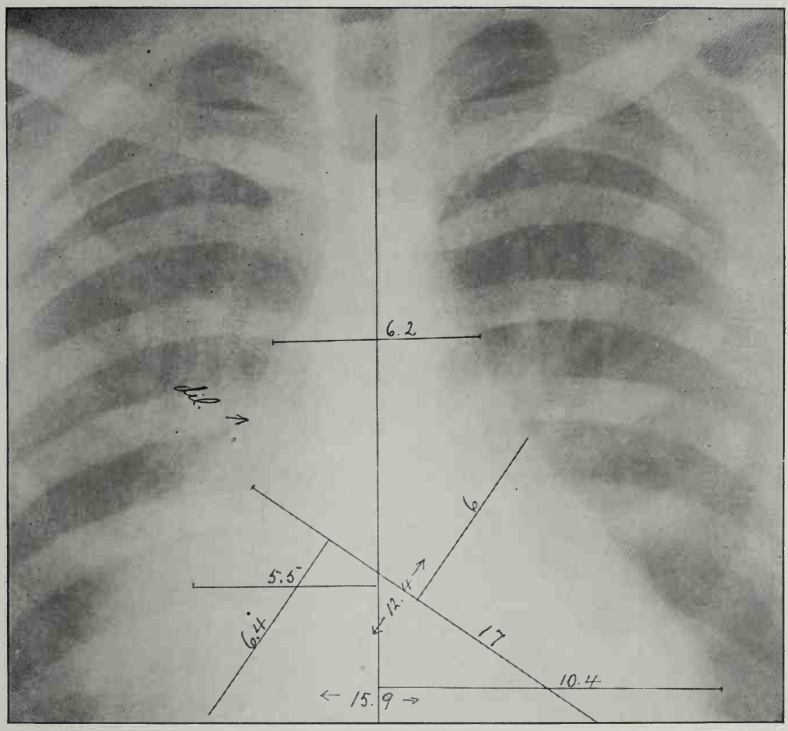

FIG. 107.—Dilatation of the ascending aorta, due to specific aortitis. The aorta is partially hidden by the shadow of the right auricle.

of the vertebræ better than the anteroposterior view, and also locate the mass in or behind the posterior mediastinum. Rarely, a large amount of pus may form in the mediastinum, following infection of the glands or pleura. The radiographic appearance in these cases may closely resemble that of fluid in the pericardium. The increase in the mediastinal shadow may be unilateral or bilateral. Its borders are sharply defined and do not pulsate. The shadow of

the heart can be distinctly seen through it, which usually serves to distinguish this condition from fluid in the pericardium.

In an occasional case of cardiospasm the esophagus may be dilated to such an extent as to appear as a long, smooth shadow curving outward into the right lung fields. It may be recognized by the fact that it continues upward above the clavicles and by the use of a barium meal. It must not be forgotten that diverticulum

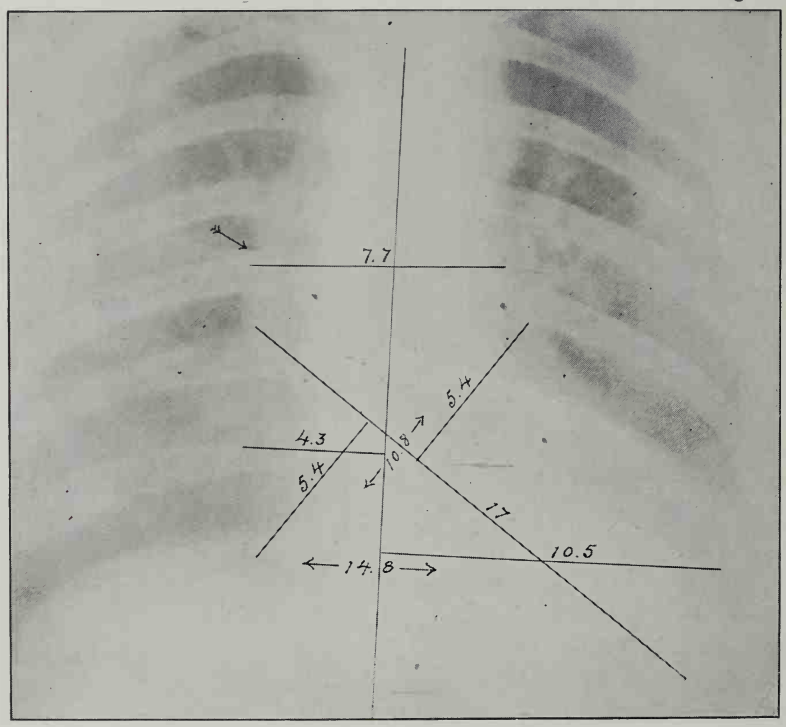

FIG. 108.—Dilatation of the ascending aorta, due to syphilitic aortitis. A well-marked case.

of the esophagus may simulate mediastinal tumor, encapsulated empyema and aneurysm.

Diaphragm.—Normally the diaphragm curves smoothly from the pericardium downward to form a sharp angle with the pleura. The right side is higher than the left (one or more centimeters), and in some cases shows several small curves near the dome due to inequalities in the liver which have no significance. Fluoroscopically

it should move freely and equally on the two sides both on quiet and deep respiration.

Changes in Outline.—Marked irregularities on the surface of the liver may be transmitted through it. Bands of adhesions to the pleura or the chest wall may elevate small stringy or triangular areas.

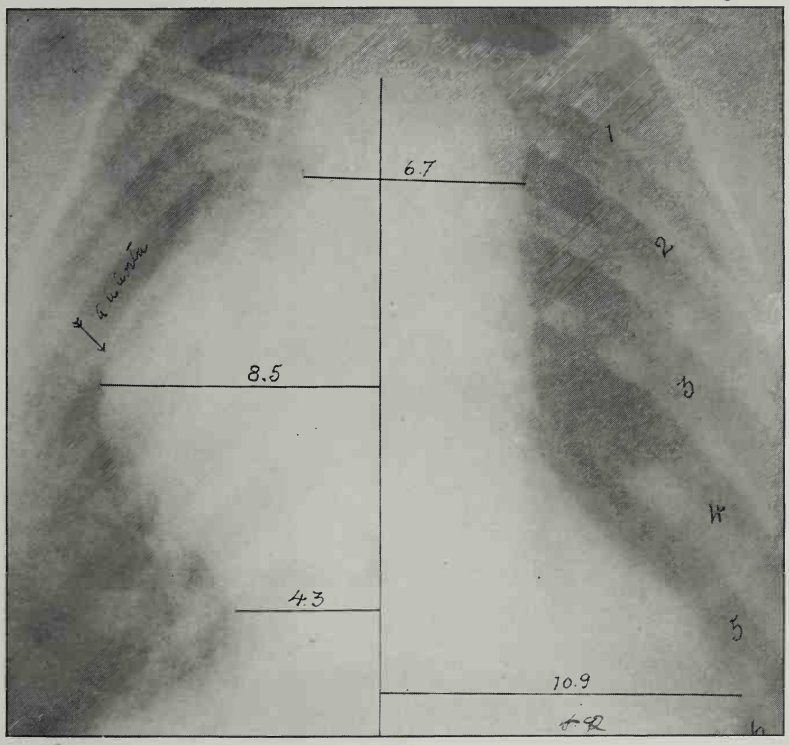

FIG. 109.—Aneurysm of the ascending aorta.

Changes in Motility.—Slight limitation of motion may be observed when the patient is breathing quietly, which disappears completely with deep respiration. The finding is usually due to pain, and its cause is frequently found below the diaphragm. Bilateral limitation of motion may be due to emphysema, ptosis, ascites, peritonitis, pleuritis at the base of both lungs, or fibrosis from an old inflammatory process. When unilateral, we must look above the diaphragm for tuberculosis, or disease of the pleura on that side or

below it for an inflammatory process such as a diseased appendix or gall-bladder, subdiaphragmatic liver or perinephritic abscess. Paradoxical excursion of the diaphragm is seen in paralysis of the phrenic nerve and diaphragmatic hernia. The affected side rises during inspiration and falls during expiration.

Changes in Position.—It is low in ptosis and emphysema. It is high in adiposity, ascites and subdiaphragmatic abscess, eventration and hernia of the diaphragm. Eventration and hernia are both more common on the left side. In eventration, although con-

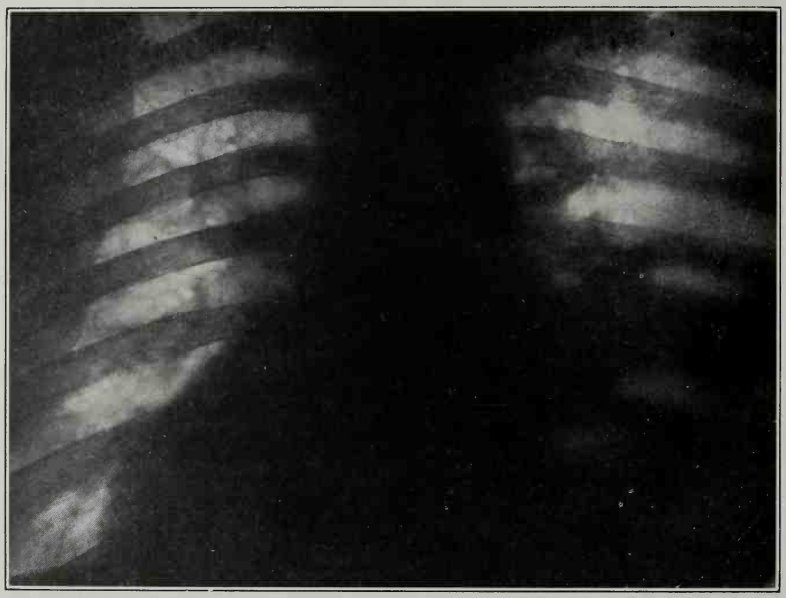

FIG. 110.—An abscess of the liver which contained gas as well as pus. The plate was taken with the patient in the upright position.

siderably elevated, its contour is preserved and movement is normal in direction though limited. In hernia its outline is obscured and its movement paradoxical. In both cases the barium meal will demonstrate the position of the abdominal viscera. When emphysema is present both the inspiratory and expiratory movements are limited in all positions of the patient. With visceroptosis the expiratory movement is not limited, and the inspiratory only when the observation is made in the upright position.

Pleural effusions obliterate the costodiaphragmatic angle if small or the entire diaphragmatic shadow if they are extensive.

It is worth noting that in rare cases fluid may be obtained from a chest that is roentgenologically negative. Errors of this kind can usually be avoided by taking plates in the upright position.

Subdiaphragmatic Abscess.—Subdiaphragmatic abscess causes marked upward displacement of the shadow of the diaphragm. The top is usually considerably flattened and excursion is abolished if the collection of pus is in contact with the diaphragm. Otherwise

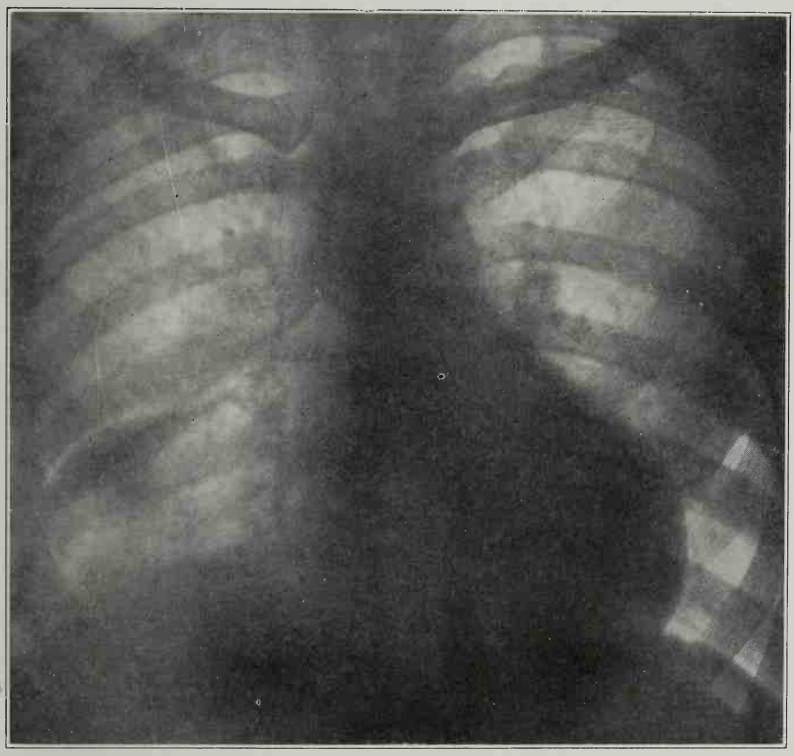

FIG. 111.—Encapsulated empyema. The process is between the lower and middle lobes.

it will be much limited. When the infection has extended into the chest and involved the pleura the outline of the diaphragm becomes obscured and it is not possible to determine from the roentgenogram whether or not there is disease below it. Rarely an abscess below the diaphragm contains a gas bubble, below which there is a fluid level which changes with change of position of the patient. For this reason these cases should always be examined in the upright

position when possible. Encapsulated fluid above the diaphragm may strongly resemble subdiaphragmatic abscess if the collection of fluid is between the lung and diaphragm.

LUNG FIELDS.

Technic.—Lung examination should include both fluoroscopy and plates, preferably in the erect position. When the patients can hold their breath, stereoscopic plates have great value but they are not necessities. In certain conditions examination in the prone, oblique and lateral positions should be made. It is usually advisable to take both anteroposterior and postero-anterior plates. The number and position of the plates to be taken may be determined at the fluoroscopic examination.

Normal Lung.—The normal lung markings consist of small areas of density at the hilus which often show calcified spots, and strands of density corresponding to the bronchial tree spreading out through the lung fields for a considerable distance but never quite reaching the pleura. The descending bronchi on both sides are usually more dense than those above. The fields are of equal density on the two sides. They are slightly obscured by the pectoral muscles and the breasts in postero-anterior views and there is usually some slight haziness in the left base in the region of the apex of the heart.

Pathological Changes.—Diffuse increase in density on one or both sides is found in thickened pleura, fluid, consolidation or bronchial stenosis. A general increase in radiability is due to emphysema. Local areas of increased radiability may be due to pneumothorax or cavity formation. Localized areas of increased density are most likely to be abscess, localized pneumonia or malignancy.

Increase in size of the root shadows may be due to infection or tumor.

Increased thickening of the bronchial markings means infection, fibrosis or malignant disease. Fine mottling along the bronchi is usually due to the early manifestations of tuberculosis. Fine mottling in the lung tissue usually means tuberculosis, fibrosis or malignancy. Coarse mottling in the lung tissue is due to bronchiectasis, tuberculosis or metastatic malignancy. Displacement of mediastinal contents occurs with effusion, adhesions, fibrosis and tumors. In the case of tumors, displacement is often toward the side affected by the growth.

Pleura.—The normal pleura casts no appreciable shadow and is therefore not visible on the plate or screen. Thickening occurs as a result of inflammation and may obscure all of one or both chests or may be limited to the base or apex. The shadow is fairly dense although the ribs can usually be seen through it. A thin, curved, white line, convex upward, extending across the chest is occasionally seen as the end-result of an interlobar pleurisy. Adhesions appear as strands of increased density. At the apex their appearance may suggest cavities.

Pleural Exudate.—Fluid in the pleural space usually gives a shadow of extreme density located at the base, obscuring the ribs and diaphragm with a superior margin which curves upward toward the chest wall in the axilla, unless pneumothorax is present, when it will show a fluid level which changes as the patient's position is shifted. In the prone position the shadow is uniform throughout the chest and often resembles that of thickened pleura. If an effusion is extensive, there is usually displacement of the heart and great vessels. The apex is usually clear. At times fluid may appear as a zone of increased density about the periphery of the lung.

Encapsulated fluid gives a dense, sharply defined shadow in contact with the pleura. It is most common at the base, along the axillary border or between lobes. When the collection is between lung and diaphragm it may simulate subdiaphragmatic abscess.

The difference in the density of the shadow cast by an exudation or effusion and that cast by pus is very slight, and usually it is not possible to differentiate them by the roentgenogram alone. The shape and position of the shadow, however, may be of considerable help. Simple fluids are seldom encapsulated, and for this reason are seen first in the most dependent portions of the chest, usually the costophrenic angles, from which they extend upward and inward—the axillary margin always remaining the highest point, and the upper border maintaining its curved form.

An empyema may form in the same manner; but as it is frequently encapsulated, the curve of the upper margin is often absent, and there may be an area of normal lung below it.

Pneumothorax.—Pneumothorax is characterized by the presence in the periphery of the lung field of an area of greatly increased radiability from which the lung markings are absent. Its borders are sharply defined and consist of the walls of the chest cavity and the margins of the compressed lung. When the pneumothorax is complete and there are no adhesions, the lung collapses to a lobu-

lated mass at the hilus in which can usually be seen the suggestion of lung marking. In the presence of pleural adhesions where the collapse is incomplete, the shadow of the pneumothorax may be divided by bands which give it a sacculated appearance and pneumothorax and lung tissue may overlap each other. A small localized pneumothorax may be difficult to detect unless it is seen in profile; otherwise it appears as an area of somewhat increased radiability

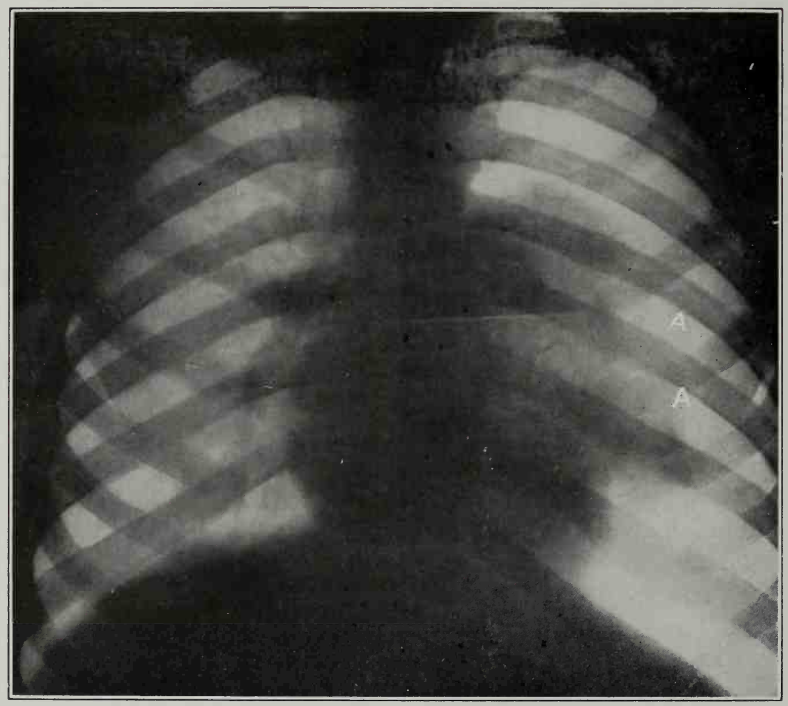

FIG. 112.—Pneumothorax, with complete collapse of the left lung. Note the absence of lung markings and increased radiability at *a*.

overlaid by normal lung markings. This should not be confused with large cavities which occur in the substance of the lung and may or may not have well-defined borders.

Calcifications frequently appear in the pleura in a form of ragged plaques or lines which occur in any portion of it.

Malignancy of the pleura gives a shadow suggesting a small effusion or greatly thickened pleura, but the diagnosis can seldom be made from the roentgenographic evidence alone. Fluid in, or

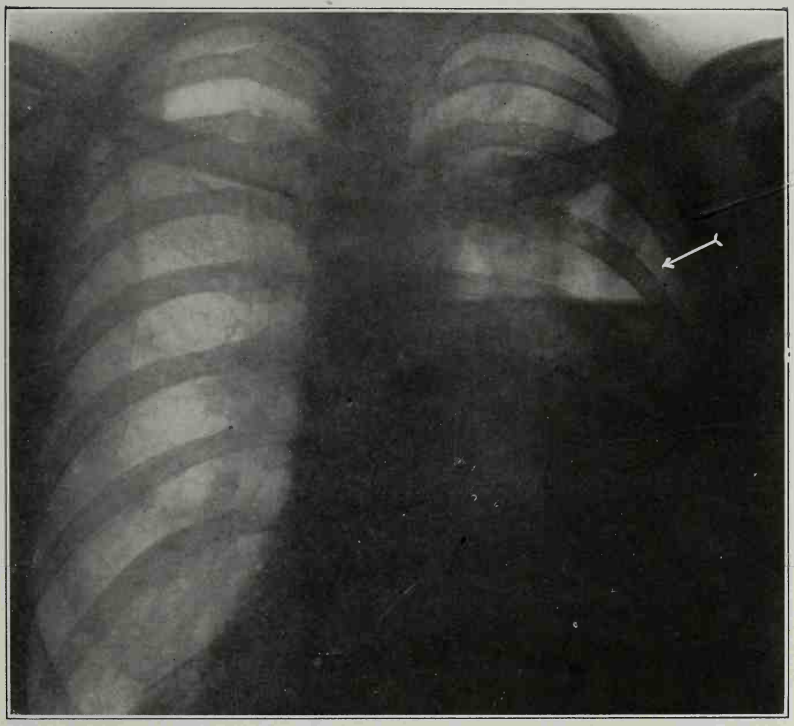

FIG. 113.—Hydropneumothorax. This plate was taken with the patient upright. The fluid level is well shown at about the middle of the left chest.

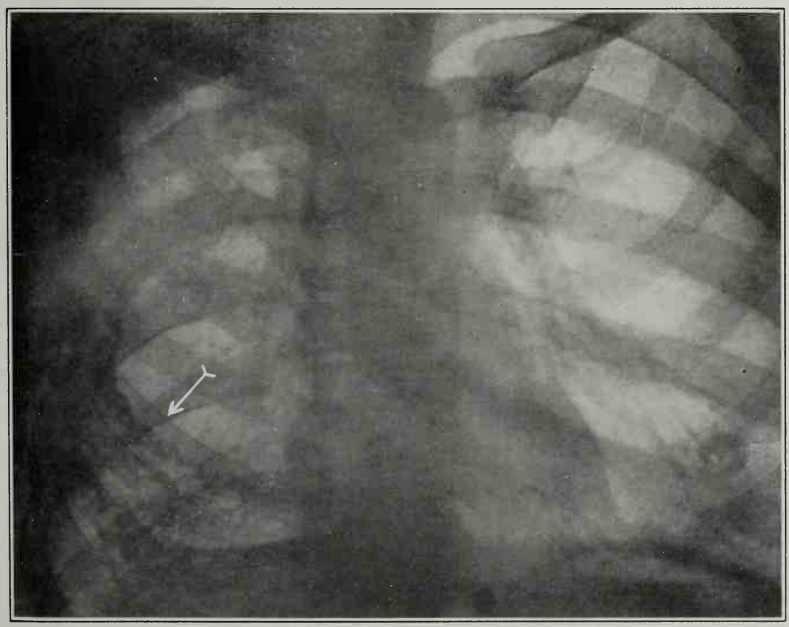

FIG. 114.—Old empyema, with calcification in the right pleura.

disease of the pleura, may be confused with a process in the lung structure. This is especially true if the examination is made in one position only. But if the patient is rotated during the screen examination or if stereoscopic plates are taken the true location of the process can usually be demonstrated. The diseases which are apt to cause confusion, are: lobar and bronchopneumonia, or lung abscess.

In lobar pneumonia the shadow usually occupies the position of one or more lobes of the affected lung, and the shadow is less dense than that of fluid. It does not obliterate the shadow of the ribs, diaphragm or heart.

Bronchopneumonia and lung abscess, unless complicated by empyema, present shadows which are well within the lung structure, and a bright area can usually be demonstrated between them and the chest wall.

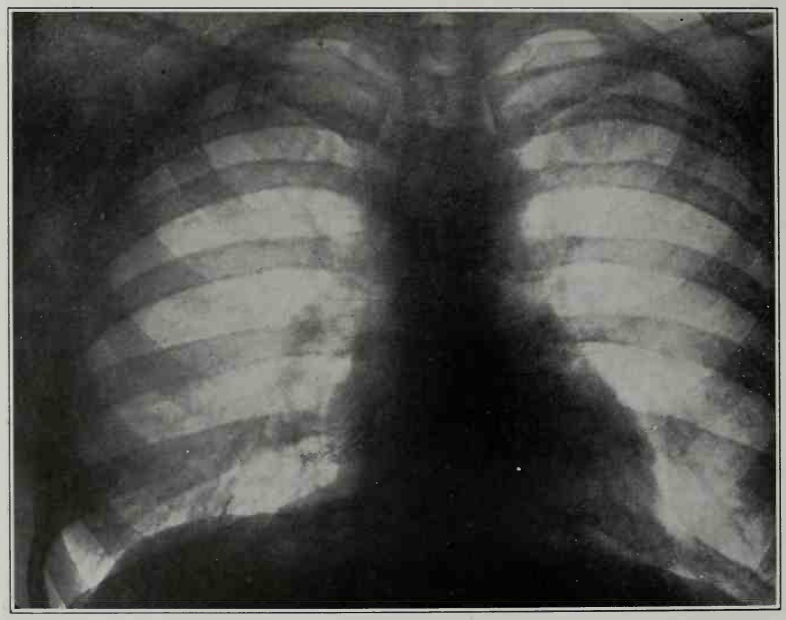

FIG. 115.—Peribronchial tuberculosis. Advanced tuberculosis two years later.

Tuberculosis.—The primary focus in tuberculosis is probably in the periphery of the lung but it is not always evident. However, we see an increase in the root shadows as a result of glandular involvement which, particularly in children, is often marked. In

the acute stage their outlines are blurred and indistinct. If healing occurs the shadows gradually diminish in size, increase in density and sharpness of outline, and subsequently show areas of calcification. As the infection progresses, the next change is general thickening of the bronchial markings along the track of the disease, usually toward one or both tops. When this has occurred the patient will usually show dulness at the affected area clinically. Because of the normal thickening toward both bases this stage is difficult to

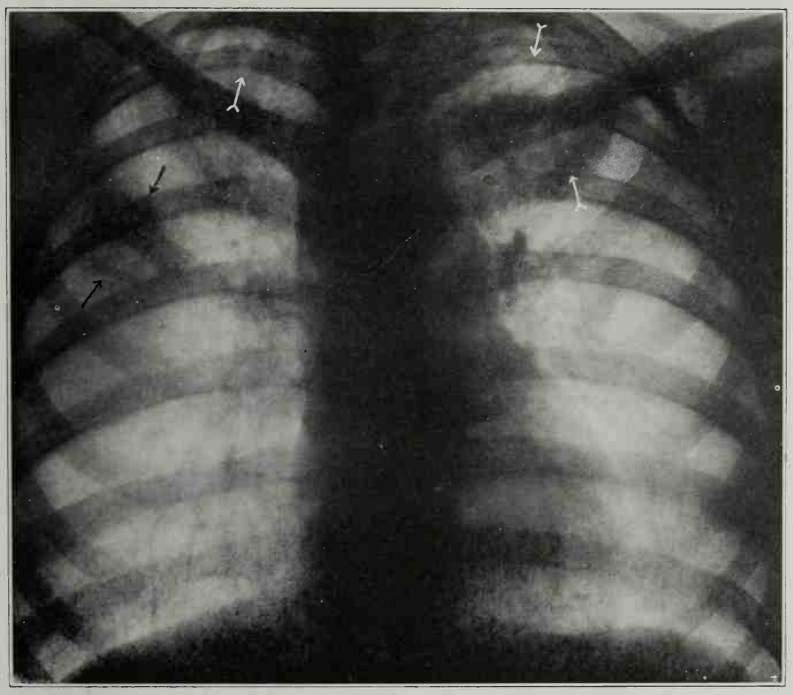

FIG. 116.—Tuberculosis at both apices.

recognize when the extension is downward but it is much less common in this situation. Plates of most adult lungs show a certain amount of thickening of the bronchial markings as a result of previous infections and have no particular significance. When due to tuberculosis, the changes are permanent. The demarcation between the normal and the pathological is not sharp and it takes considerable experience in the observation of plates, combined with all that can be found by clinical methods, to establish a correct diagnosis.

If the process continues, small bead-like masses appear along

the course of the thickened bronchial shadows and fan-shaped areas of filmy density may be seen with their bases on the pleura and apices extending inward toward the thickened markings. These fan-shaped areas are probably the earliest evidence of definite involvement of the lung parenchyma, but unfortunately they are not commonly seen and they may occur in other infections.

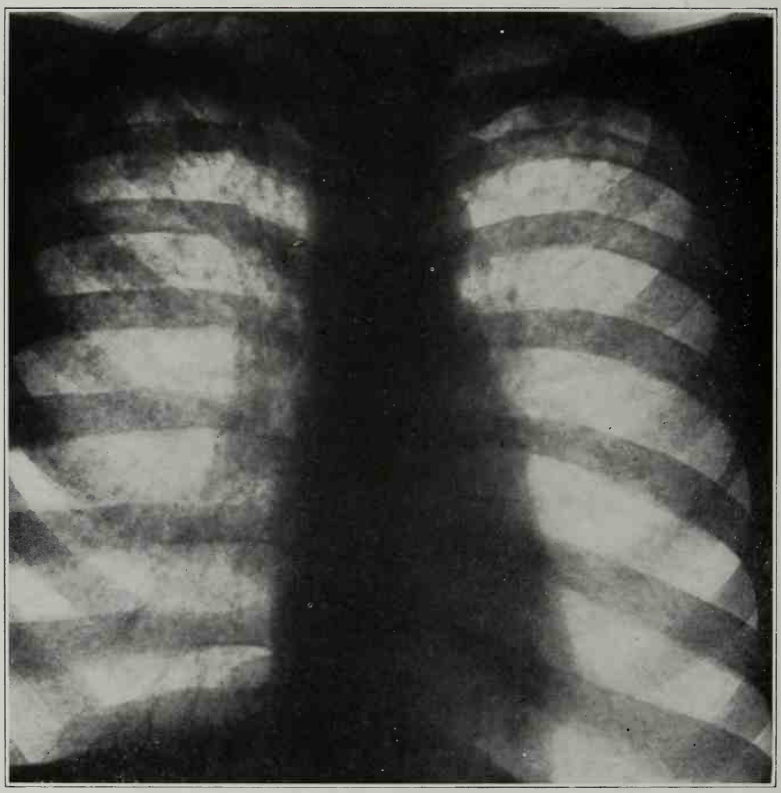

FIG. 117.—Miliary tuberculosis of the lungs. The changes are most marked in the upper lobes.

The next stage is the appearance through the diseased area of finely stippled grayish spots, apparently independent of the bronchial markings now extended to the periphery of the lung. These spots mean definite involvement of lung tissue and at this time rales are beginning to be evident upon clinical examination. This characteristic fine mottling is the only sure basis for a roentgen diagnosis of active tuberculosis. It is seen in its most typical form in the cases of miliary tuberculosis.

With the further progress of the disease there occurs an enlargement and fusion of these spots and their extension to new areas, resulting in coarse mottling and finally evidence of cavity formation. Areas of healing may occur at any stage, or progress and healing may be simultaneous so that it may be impossible to decide from roentgen evidence alone whether a case is active or quiescent. In general, active lesions are dim, gray and blurred; healed ones are more dense and sharply outlined.

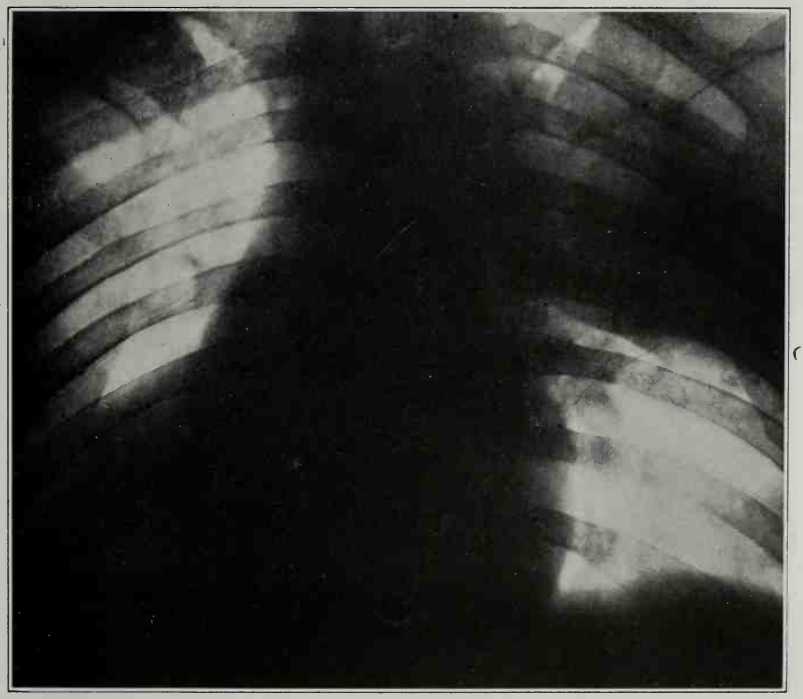

FIG. 118.—Lobar pneumonia. The process is in the lower part of the right upper lobe.

The only condition which must be differentiated from extensive tuberculosis is that seen in pneumonoconiosis, where the fibrous changes in symmetrical portions of both lungs cast a cotton-like shadow very similar to that of fibroid tuberculosis. However, the apices are usually not involved and the patient will give a history of having worked underground or in a dusty occupation and his physical signs are not those of a tuberculous process of similar extent.

Miliary tuberculosis presents a characteristic, fine, hazy mottling scattered throughout the lung fields which must be differentiated from metastatic malignancy and from pneumonoconiosis. Metastases in rare cases appear as definite small discrete areas of increased density scattered throughout both lungs, but the spots, while approximating those of miliary tuberculosis in size, are more dense and more sharply outlined. From pneumonoconiosis it may be

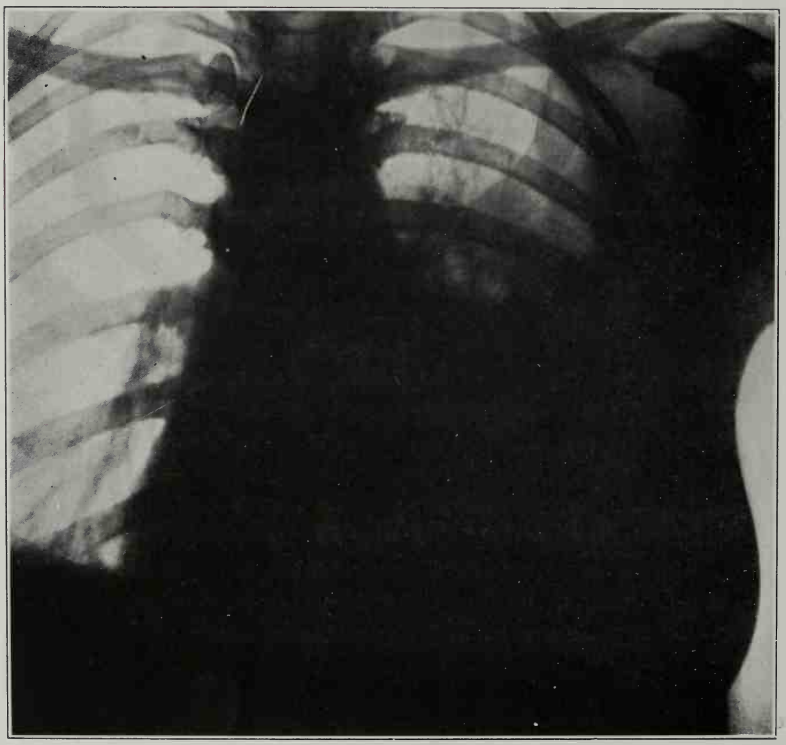

FIG. 119.—Pleurisy, with effusion at the left base. Note the position of the shadow in the axillary border and the displacement of the heart to the right.

differentiated by the fact that it is a more diffuse process involving all portions of the lung, whereas pneumonoconiosis typically involves symmetrical areas and spares the apices. The mottling in the latter is much finer and the dense spots are smaller than those seen in tuberculosis.

Lobar Pneumonia.—Lobar pneumonia is characterized by areas of increased uniform density which are sharply defined and, when fully developed, usually occupy the position of a lobe. In the early

stages the shadow, while uniform, is less dense and may be triangular in shape with the base on the pleura and the apex toward the hilus. The lung markings distributed to this area are thickened and the hilus glands are enlarged. It has been observed in children that dulness and changed breath and voice sounds are not ordinarily perceptible until the shadow reaches the hilus.

The character of the shadow changes with the progress of the disease and as resolution appears it becomes distinctly mottled. After the shadow itself has disappeared, thickened bronchial markings or large glands may persist for a considerable time. It must be differentiated from fluid where the shadow is more dense, does not conform to lobar outlines, and displaces the heart and vessels.

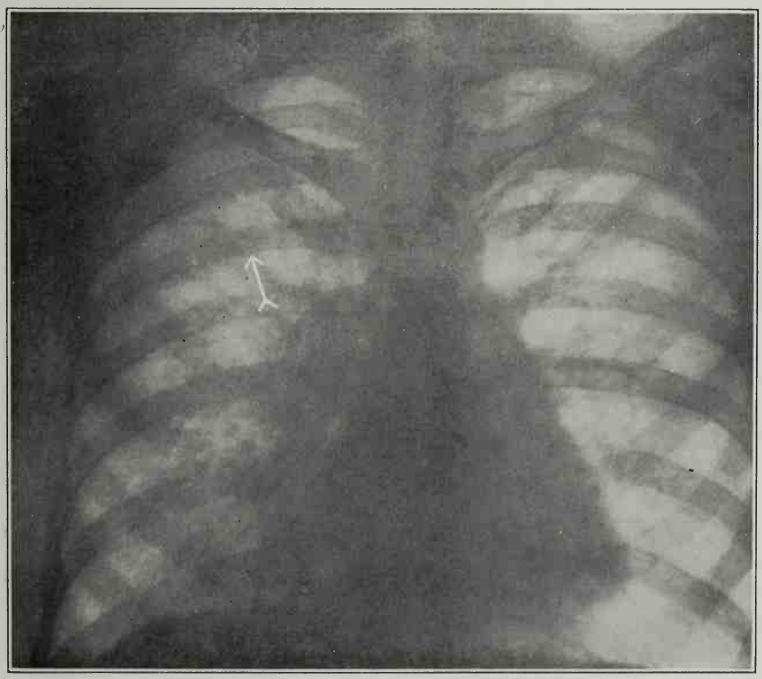

FIG. 120.—Bronchopneumonia following operation upon the nose. The patient died two days after this plate was taken and the findings were confirmed at autopsy.

Bronchopneumonia.—Bronchopneumonia occurs more frequently than is generally recognized. Owing to the absence of physical signs the diagnosis may depend largely upon the roentgen examination and the history. The appearance is that of single or multiple areas

of increased density with hazy outlines, usually situated near the course of the larger bronchi. The differentiation from abscess, bronchiectasis and malignancy depends largely upon the course and clinical history.

Unresolved Pneumonia.—Unresolved pneumonia gives a shadow resembling that of pneumonia. It must be distinguished from an interlobar empyema, tuberculous pneumonia, or bronchial stenosis largely by the clinical and laboratory findings. It has been noted that unresolved pneumonias may disappear after mild roentgen radiation.

Bronchitis.—Bronchitis, when acute, gives no characteristic picture. The chronic inflammations appear as an increase in the size and density of bronchial markings and glands.

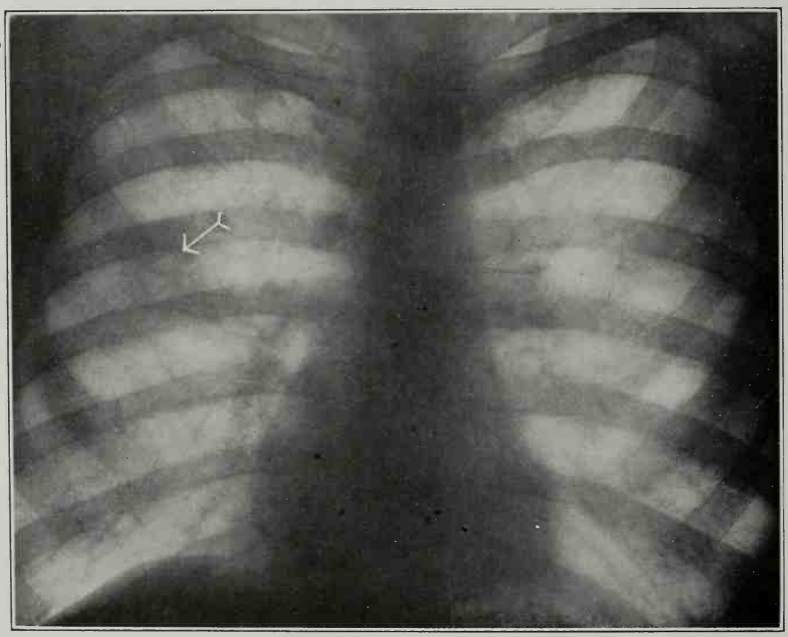

FIG. 121.—Lung abscess. The cavity of the abscess can be seen as an area of diminished density in the center of the dull area in the right chest.

Lung Abscess.—Lung abscess usually follows acute infections or the inspiration of infected material at operation or of foreign bodies. Clinically it is a disease of symptoms rather than physical signs, so that the roentgen examination is of the greatest help in indicating the site and extent of the process from its early stages. The lesions

are usually single, although they may be multiple and may occur in either lung field, showing, however, a decided preference for the bases, particularly the right. They assume the form of irregular areas of increased density which are most marked at the center, fading out toward the periphery. Cavity formation is usually present in the areas of infiltration. When filled with fluid they are indistinguishable from the general shadow about them but the larger ones become very evident when filled with air, particularly if they contain sufficient fluid to cause a fluid level. When empty they are seen as round areas of greatly diminished density and, if a fluid level is present, its surface shifts according to the position of the patient. Small cavities may be entirely overlooked particularly if filled at the time the examination is made. They are best demonstrated in the upright position, and the screen examination is often more reliable than the plate. They should always be carefully looked for as they are of great diagnostic importance. The bronchial markings distributed to the areas involved are enlarged and coarse and the hilus shadows are increased in size. Abscesses may persist for a long time as areas of thickening or heal spontaneously without leaving a trace of their presence on the roentgenogram. Their localization is often disappointing to the surgeon because of the zone of pneumonic infiltration about them which magnifies the area of involvement. If the cavity of the abscess can be seen, its location is best accomplished by rotating the patient during the screen examination, and in this way finding the point on the chest wall which is nearest to it. This point should be marked on the patient's skin, and if possible should be the point selected by the surgeon for approach. The distance from the point marked to the cavity should be indicated by a second mark on the chest where the shadow of the cavity appears when viewed with the parallel ray from the tube passing through the chest at right angles to the one of approach. Abscesses may be confused with tuberculosis, bronchopneumonia bronchiectasis, and rarely metastatic malignancy. The similarity to tuberculosis lies in the occurrence of cavities. In tuberculosis there is other roentgen evidence of the disease in the form of characteristic mottling elsewhere in the lungs and especially at the apices and the cavities are usually empty, while the cavity of an abscess usually contain some fluid. Abscess is more common at the bases and the apices are clear. Bronchopneumonia may be differentiated by the fact that it gives a shadow of more uniform density and there is

no cavity formation. Bronchiectasis is usually a diffuse process and the bronchial changes are more extensive. However, these two conditions blend into each other at times. Small multiple abscesses may be mistaken for metastatic malignancy; but the history and clinical course will determine the diagnosis.

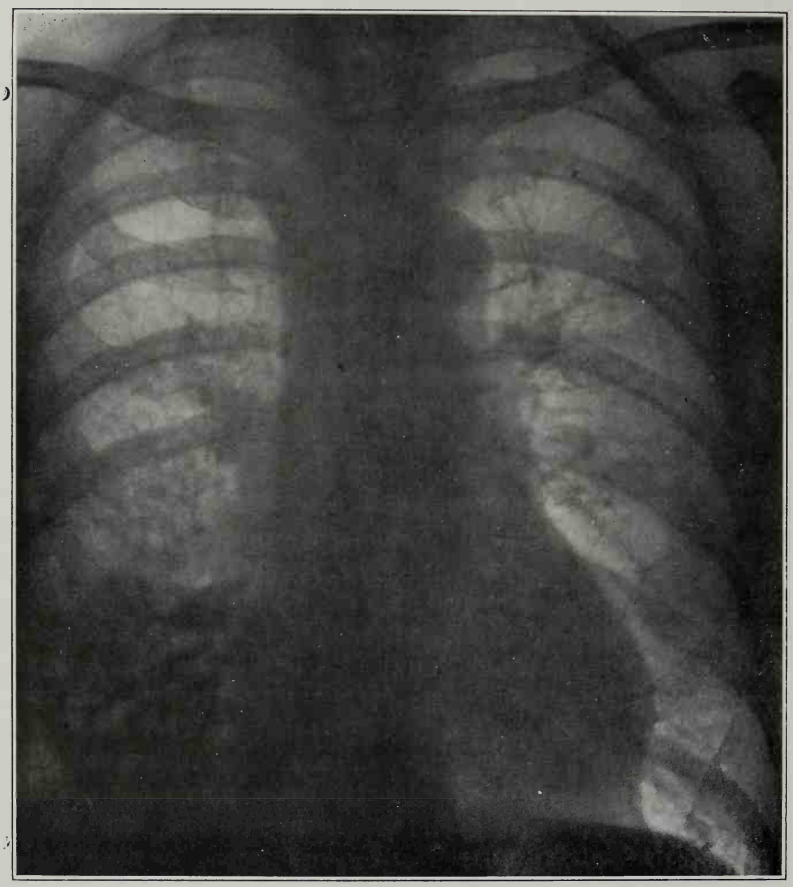

FIG. 122.—Bronchiectasis. The process is fairly well localized in the right lower chest. The dilated and sacculated bronchi are visible.

Bronchiectasis.—The characteristic picture in a well-advanced case is an extensive thickening of the lung markings along the course of the larger bronchi and enlargement of the hilus glands with the presence of single or multiple areas of increased density in the lung fields near the bronchi, which may show considerable

change in plates taken before and after evacuation. Cavities can often be demonstrated. In the early stages the picture is much less characteristic and depends upon the demonstration of small ring-like shadows of dilated bronchi which, however, are usually obscured by the infiltrated lung about them. There is an associated emphysema in the long-standing cases.

Foreign Bodies.—Foreign bodies most commonly lodge in the right bronchus and may be recognized if of sufficient density to cast a shadow. Their presence may be the cause of an area of increased density due to a localized pneumonia about them, to abscess formation or to collapse of one or more lobes as a result of bronchostenosis. Occasionally the foreign body may allow air to pass into, but not out of the affected lobe or lobes, producing a localized emphysema. Examination for foreign bodies should include observation of the entire respiratory tract from different angles. A lateral view of the chest is often helpful, and inspection of the larynx and the neck should be included.

Bronchostenosis.—Bronchostenosis gives a uniform dense shadow throughout the area supplied by the affected bronchus and the movements of the diaphragm are limited on the affected side. It occurs as a result of inspired foreign bodies, aneurysm, tumors or lues.

Gangrene.—Gangrene casts an extensive shadow which may occupy one entire lung field. Its characteristic features are the presence of large irregular areas of diminished density and a general coarse mottling of the lung. The heart and mediastinal contents are not displaced. This appearance may be simulated by a lung which has recently expended after a prolonged pneumothorax.

Primary Malignancy.—Primary malignancy of the lung is rare. It is practically always unilateral. The usual growth is a carcinoma which occurs in two types, nodular and infiltrating. The former consists of dense, rounded masses, sharply marked off from the lung tissue, occurring near the hilus. Ragged, irregular cavity formation in the tumor mass sometimes occurs. In the infiltrating type, the tumor arises from a bronchus and infiltrates the lung along the bronchial ramifications. The growth may be confined to the bronchial tree so that it appears as an increase in density of the lung markings in the affected area, or it may involve surrounding lung tissue and be seen as a mass with fairly smooth edges except along the advancing margin which is irregular and tends to grow in the direction of distribution of the affected bronchi. These

growths may also extend toward the root and form large masses at the hilus. Collapse of the lung with displacement of the heart to the affected side may take place. Fluid in the pleural space occurs early.

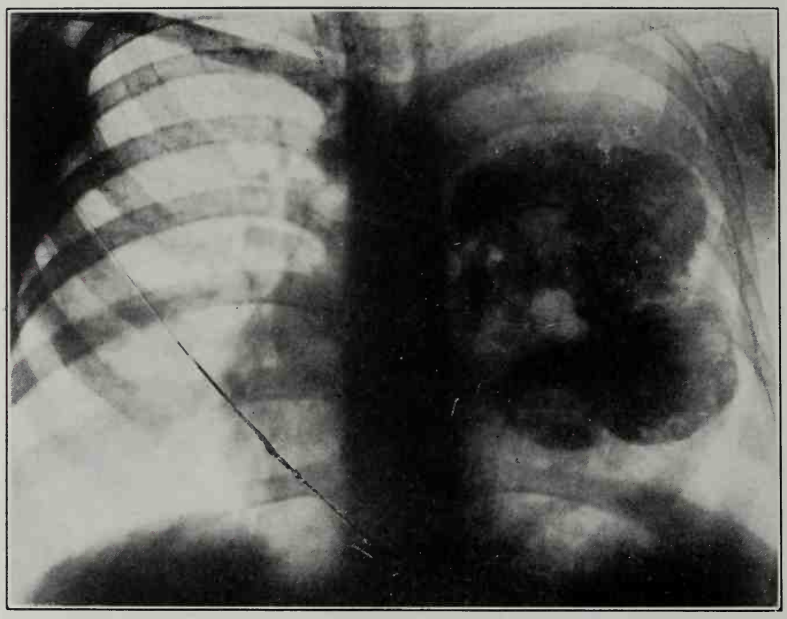

FIG. 123.—Spindle cell sarcoma of the lung. (Patient lived four years after this plate was made.)

Metastatic Malignancy.—Metastatic malignancy appears in three forms. In the first there is progressive enlargement of the hilus shadows which is unrecognizable in the early stages and unmistakable in the later ones when large masses have developed at the lung roots and usually an effusion at one or both bases. In this form a dense infiltration starts from the hilus and extends out along the bronchial markings, particularly those distributed to the middle and upper lobes of the lung. The affected bronchi become sharply defined, increased in density and at times enlarged (Fig.126). As the growth progresses there is gradual enlargement of the hilus and mediastinal shadows, and the development of effusions in the pleura. A second and perhaps more common form is that in which the growths take the form of multiple, thin, rounded plaques of variable size, with sharp margins which are scattered throughout

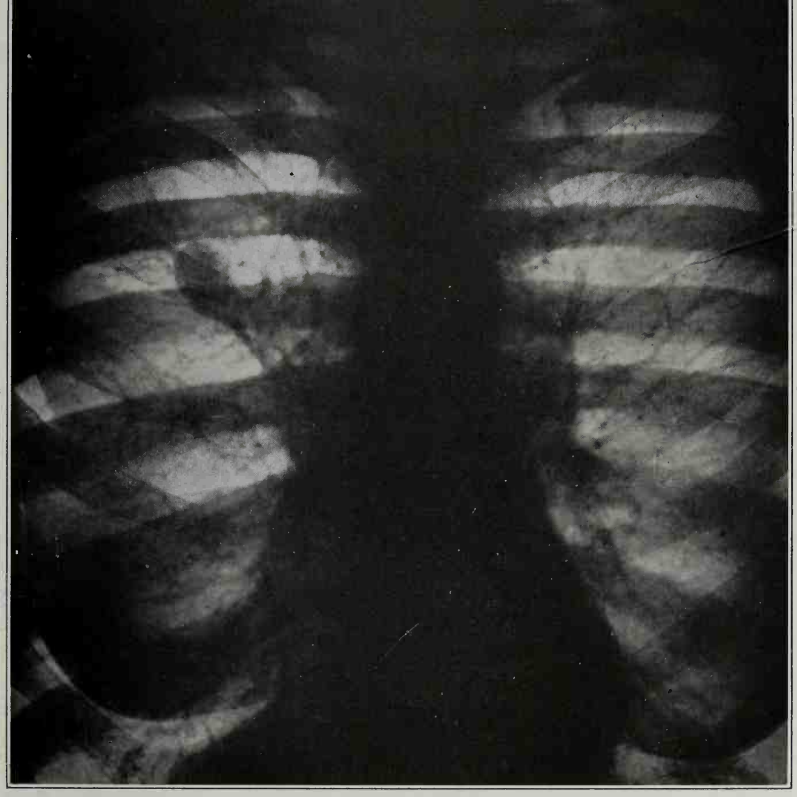

FIG. 124.—Malignant metastasis in the lungs from carcinoma of the stomach.

FIG. 125.—Metastasis. Malignant disease of the lung and pleura.

the lung fields. In the third type there is a fine mottling throughout the lung fields which may suggest miliary tuberculosis, but the small areas of increased density are a little larger, more dense, and more sharply outlined than those of tuberculosis.

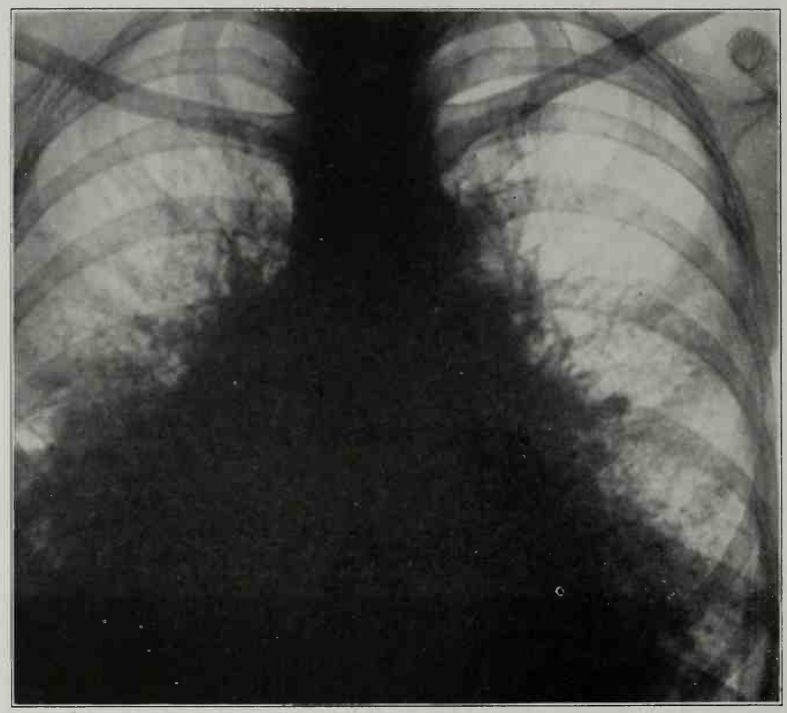

FIG. 126.—Carcinoma of the lungs. (Infiltrative type.)

Syphilis.—There is considerable discussion on the subject of lung syphilis but undoubted cases have been reported. It is evidenced in three types: In the first, there is a general thickening of all of the bronchial markings, particularly toward the hilus, giving a fan-shaped shadow radiating out into the lung fields. In the second, supposed to be gummata, there are one or more dense discrete masses to be made out in the region of the hilus. The third form occurs as a diffuse shadow obscuring one entire side of the chest which may clear wholly or in part under appropriate treatment. In this type the lesion is probably in the primary bronchus, and the finding the result of bronchial stenosis. One characteris-

tic feature of these patients is that the lesions are much more extensive than their condition would lead one to suspect.

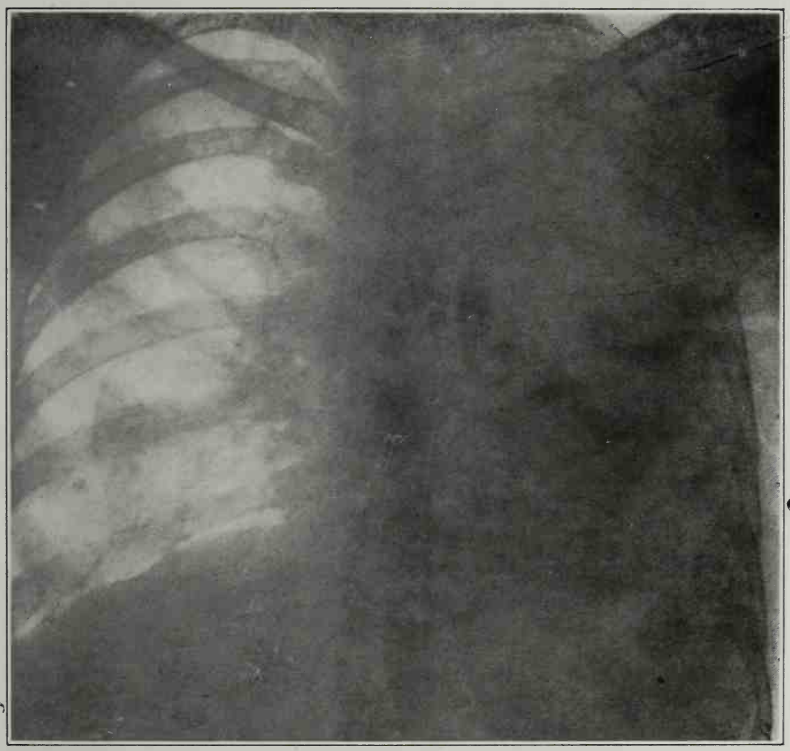

FIG. 127.—There is an extensive chronic inflammatory process involving both lungs, the left much more than the right. Clinically it was thought to be syphilitic.

Echinococcus.—Echinococcus disease of the lung occurs usually in the lower part of the lung field, and is usually a unilateral, single lesion; but may be bilateral and multiple. The findings in the roentgenogram or upon the fluoroscopic screen will depend upon the size and condition of the cyst, as well as upon its position. Three distinct appearances have been observed:

1. Closed cysts, which occur as dense, circular or oblong, sharply defined areas of increased density within the lung field. The dull area is of even density throughout, and the surrounding lung tissue is normal in appearance. The respiratory movements of the diaphragm are only slightly affected and the mediastinum is not invaded.

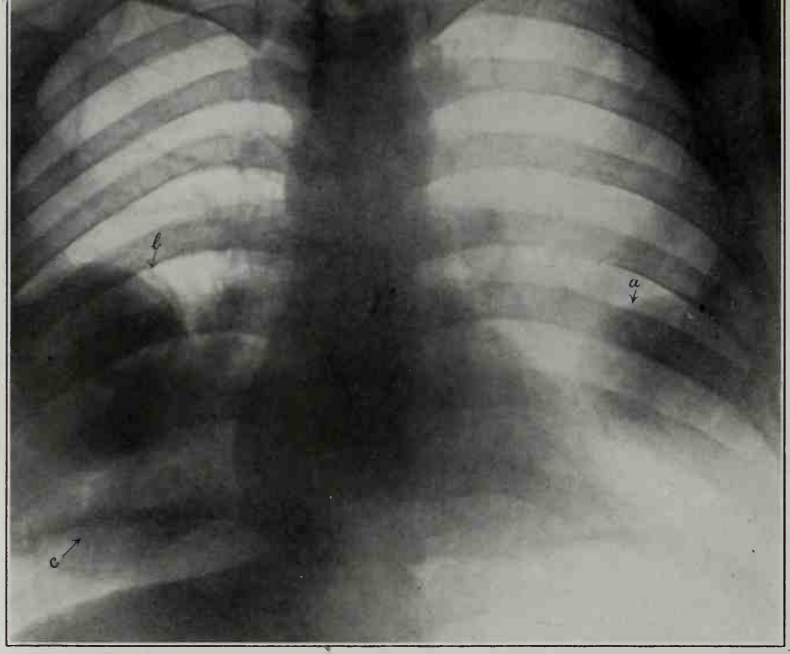

FIG. 128.—Multiple echinococcus cysts of lungs. *a*, a closed cyst; *b*, an open cyst ruptured into a bronchus; *c*, an open cyst ruptured into the lung structures.

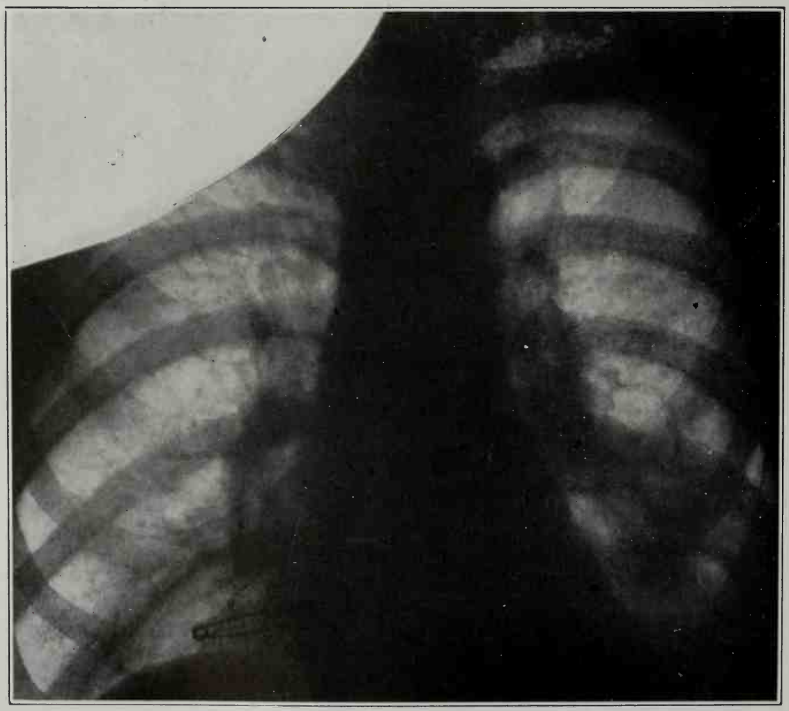

FIG. 129.—Actinomycosis of the lungs. In this case the changes are most marked around the right descending bronchus and resemble bronchiectasis.

2. Open cysts, which may be subdivided into those which have ruptured into a bronchus, and those which have ruptured into the surrounding lung. In the former the appearance is the same as in closed cysts, excepting that the involved area is of diminished instead of increased density, the appearance suggesting a large cavity with sharply defined borders.

3. When rupture occurs into the lung structures the appearance closely resembles that of lung abscess, The borders of the lesion are no longer sharply defined and the pleura may be involved, producing a marked limitation of the respiratory excursion of the diaphragm on the affected side.

Actinomycosis.—Actinomycosis usually occurs in the form of lung abscess and diagnosis is made bacteriologically.

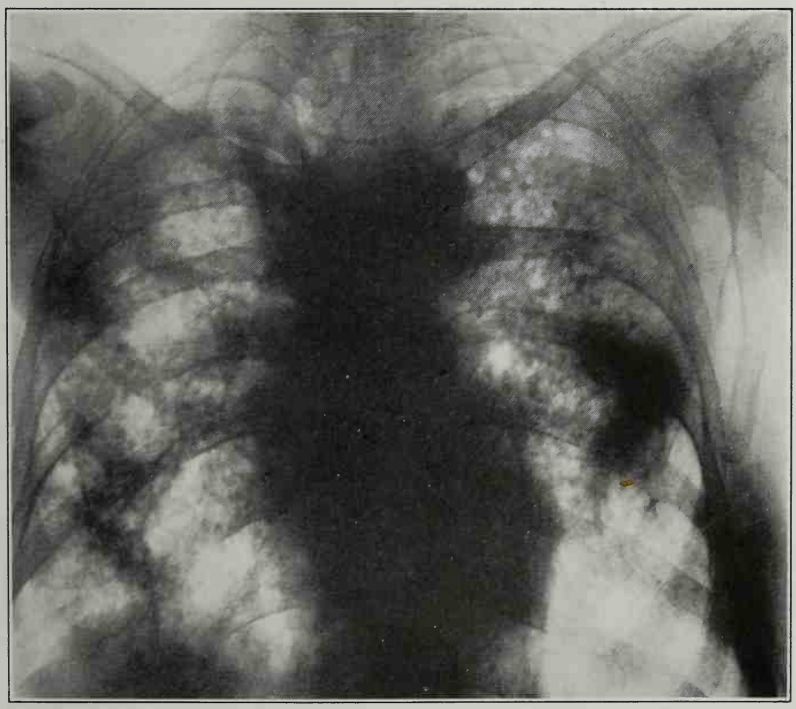

FIG. 130.—Pneumonoconiosis.

Pneumonoconiosis (Anthracosis, Chalicosis).— Pneumonoconiosis may occur as a diffuse, fine mottling symmetrically distributed throughout both lungs. The apices may be involved although

such is not usually the case. The picture is suggestive of miliary tuberculosis. However, there will usually be a long history of occupational exposure to dust and there is little or no clinical evidence of a process as extensive as the roentgenogram would indicate the mottling is more dense and the areas are more sharply defined, and more uniform in size than those of tuberculosis.

Another form of this disease is seen frequently in gold miners and pottery workers, and appears as a diffuse process involving both lungs, particularly the upper lobes, and from the plates alone cannot be distinguished from fibroid phthisis.

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CHAPTER VIII.

GASTRO-INTESTINAL TRACT.

Technic.—Both fluoroscopy and plates are necessary for adequate examination of the gastro-intestinal tract. Fluoroscopy gives information in regard to mobility and function which cannot be secured from plates, and plates give details of structure which may be overlooked on the screen so that the methods are complementary. The value of fluoroscopy depends upon the experience of the man who is doing it, and when fluoroscopy is referred to hereafter it is understood to mean that of a thoroughly trained operator. With a good screen examination, six or eight plates should be sufficient in most cases. The secret of success in this work is thoroughness, which is more essential here than in any field of roentgenology. Examinations must be frequently repeated and the patient adequately studied before an opinion is rendered. As far as possible, a routine technic should be employed throughout. There should be no preliminary catharsis. A standard meal of uniform amount and composition should be administered to the patient at about his customary meal time. The barium may be given in 8 ounces of buttermilk, malted milk or potato starch gruel and the original meal may be followed along its course or the double meal may be employed. In the latter method the patient should receive his barium in a carbohydrate breakfast of at least 16 ounces, reporting for examination six hours later, when the position of the morning meal is observed and a second standard meal administered. This latter method is the one most in use in the larger clinics, perhaps because of the saving in time it effects. It will be found thoroughly practicable in most cases. The patient should be examined in the standing, prone, supine and right lateral positions. A brief knowledge of the clinical history is essential, and whether it be secured before or after the roentgen examination is a matter of personal preference, but the roentgen findings and the history must be correlated at some time before a diagnosis is made. The accuracy of the method will vary with the personality and training of the observer. The diagnoses of the average man will be about 80 per

cent. correct. With the best roentgenologists under the most favorable circumstances, roentgen findings in this field should be 90 to 95 per cent. correct.

ESOPHAGUS.

The esophagus is grossly outlined with the ordinary barium meal. For more prolonged observation, particularly in cases of suspected new growth, a thick mixture of barium sulphate and malted milk or gelatin is of great value. In the right oblique diameter the normal

FIG. 131.—Cardiospasm. Note the esophagus to the right and the round, smooth borders of the barium shadow.

esophagus is easily seen throughout its course. It presents a slight indentation at the level of the arch of the aorta and curves forward behind the heart to enter the stomach. It is smooth in outline and the opaque mass passes readily through it with a momentary pause at the arch and a longer delay at the cardia.

Pathological Esophagus.—The esophagus may be greatly dilated in cardiospasm or benign stricture. In the former, a glass of hot water may relax the spasm and allow part or all of the meal to enter the stomach. There is no discoverable irregularity in outline and the shadow ends at the cardia in a smooth, funnel-shaped mass. Dilatation of the esophagus occurring as a result of cardiospasm

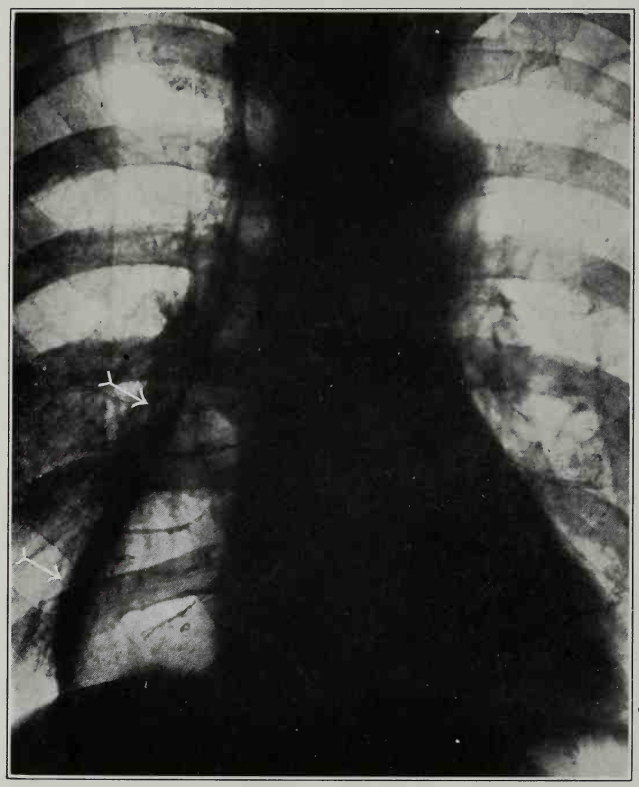

FIG. 132.—Dilated gas-filled esophagus. There is a small amount of barium in the lower part. Plate was taken with the patient upright.

may be so great that the margins of the esophagus overlap the lung field on the right side. In these cases there may be a delay of the meal above the cardia for hours or days. Malignant tumors of the cardia of sufficient extent to cause obstruction can, as a rule, be recognized by irregularities in outline of the barium mass in the lower esophagus or stomach.

Regurgitation of the meal through the cardia when the patient is prone or supine has been seen in gall-bladder disease and malignancy, particularly the latter.

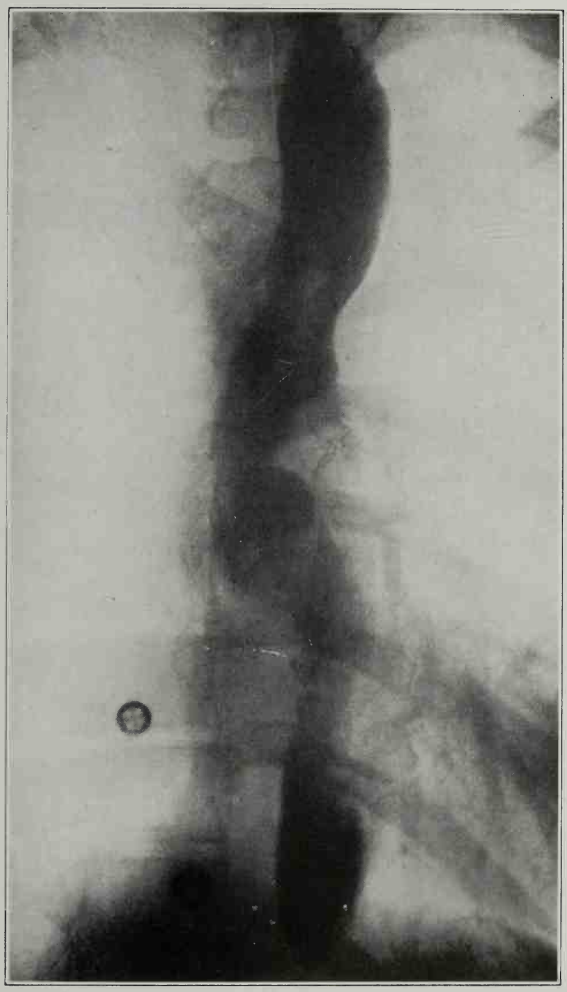

FIG. 133.—Spasm of the middle third of the esophagus suggesting malignant disease.

Changes in Position.—The esophagus may be displaced by mediastinal tumors, aneurysms, effusion, fibrosis or diseases of the spine.

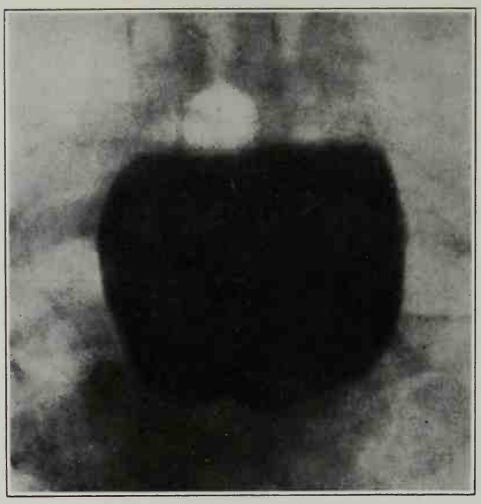

FIG. 134.—Diverticulum of the esophagus. Anteroposterior view.

FIG. 135.—Malignant disease of the esophagus at the middle third. Oblique view.

Outline.—Irregularities in outline are most commonly due to carcinoma which produces a persistent defect which is annular and ragged or mottled. It is most commonly found in the lower half of the esophagus and rarely produces dilatation of the tube above. Small, irregular annular defects have been seen immediately above the cardia in cases of esophageal varices associated with cirrhosis of the liver.

Scar tissue within the esophagus, ulceration or the ingestion of corrosives results in multiple constrictions through its course. These irregularities differ from those of carcinoma in that their margins are sharply defined and the tube above is dilated. The contraction of extra-esophageal fibrous tissue may result in constriction or sacculation.

Diverticula.—Diverticula may be found anywhere in the course of the esophagus, most commonly the upper and lower ends. They appear as rounded pouches which overflow into the esophagus through an opening at one side. It may be necessary to view the patient from several angles to bring this opening into profile. They remain partially filled after the remainder of the meal has passed on. The liquid meal is to be preferred, as solid masses may not enter the pocket.

Fistula.—In rare cases the meal may be seen to enter a descending bronchus through a broncho-esophageal fistula, usually due to carcinoma of esophagus.

STOMACH.

In the standing position the normal stomach hangs more or less centrally in the abdomen with the lesser curvature above the level of the crests of the ilia. The greater curvature lies at a variable distance below the lesser. The form and position of the stomach are determined by the architecture of the individual, the tone of the gastric wall, the tension of the abdominal muscles, the pressure of neighboring organs and the amount of the meal. Thin individuals with a narrow costal arch have long central stomachs which hang low in the pelvis. In broad, fat individuals with a wide costal arch and in those of strong muscular development the stomach is high and transverse. In asthenic states it is low and, because of the lack of tone, the meal settles in the lower pole, allowing the walls of the cardia to collapse. In the prone position the stomach swings up under the liver, lying more transversely. When empty, its walls

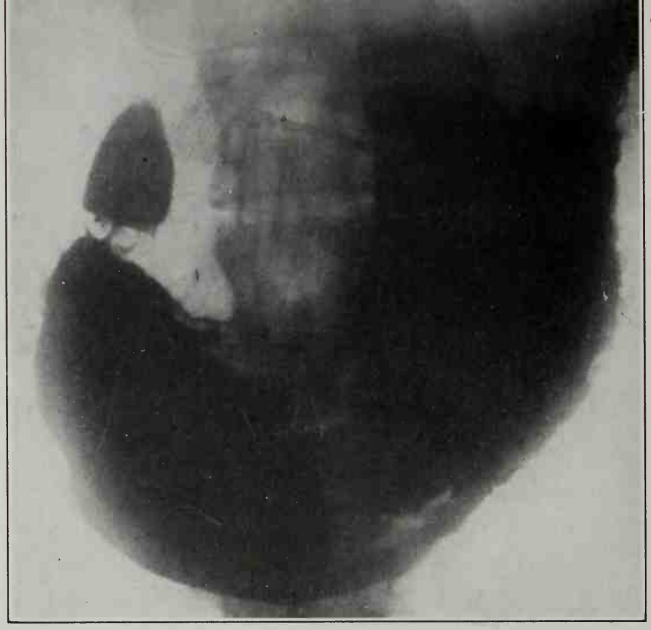

FIG. 136.—Normal stomach.

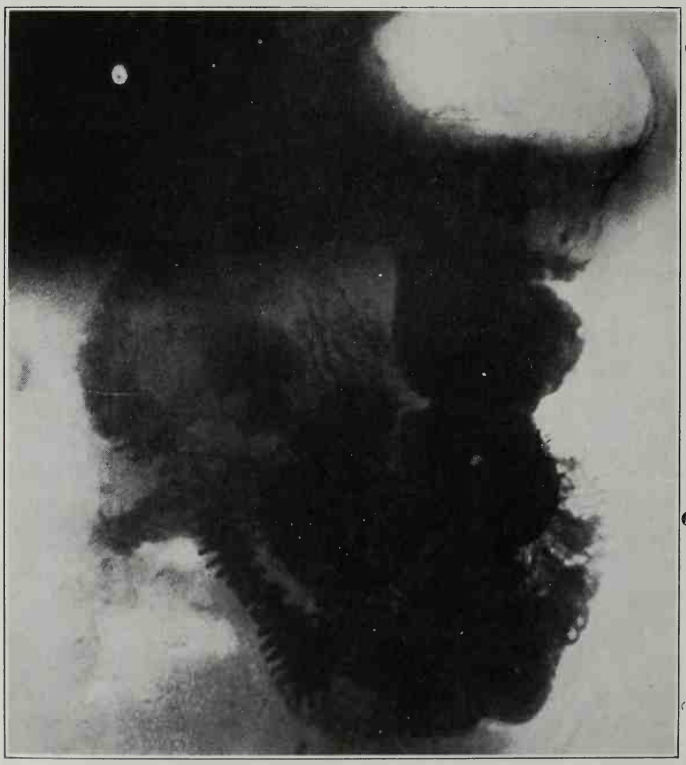

FIG. 137.—Hyperperistalsis in an otherwise normal stomach.

are in apposition except at the cardia which is dilated by the gas bubble. As the stomach fills, the meal collects in a funnel-shaped shadow below the gas bubble and gradually fills out the body and antrum. In atonic stomachs the meal passes rapidly to the lower pole which enlarges out of proportion to the body.

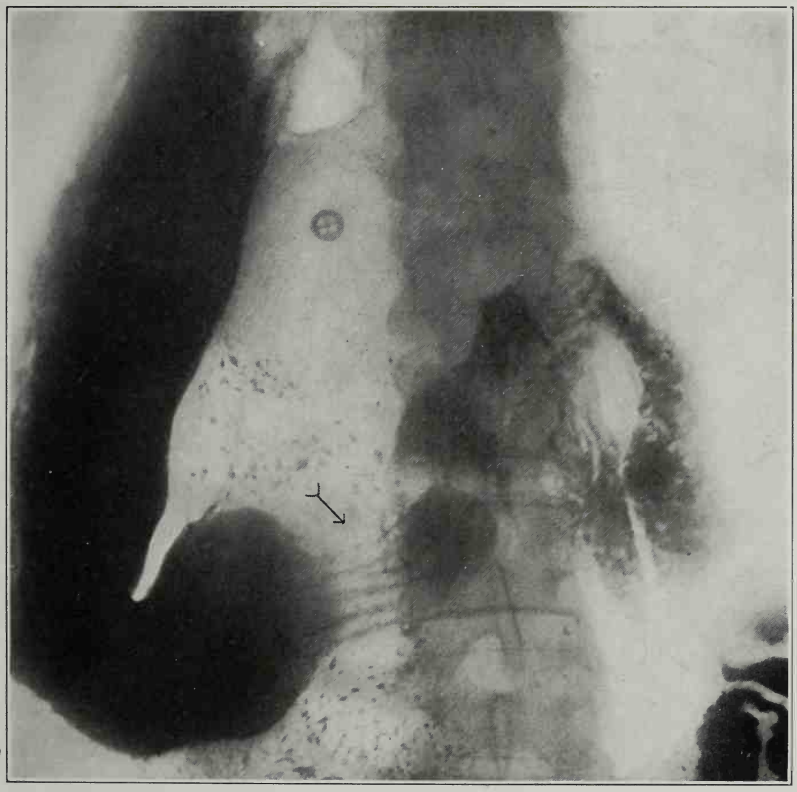

FIG. 138.—Normal stomach deformed by pressure. Plate taken with patient prone.

The outline is smooth except for indentations due to peristalsis, and a variable amount of irregularity on the greater curvature due to pressure from the colon and spleen. Small transient indentations occur on the margins of the antrum near the pylorus. They are most common on the lesser curvature and are without significance.

Normal peristalsis begins at about the middle of the lesser curvature with a shallow depression corresponding to it on the greater curvature. The waves travel toward the pylorus without interruption. They become progressively deeper as they pass forward

and may bisect the barium mass at the upper limits of the antrum. If the pylorus opens, the antrum then contracts as a whole, forcing its contents into the duodenum. If not, the waves move on to the pylorus. Peristaltic waves occur at intervals of about twenty seconds, varying with the patient and the meal used. Ordinarily no more than two or three waves are visible on a stomach

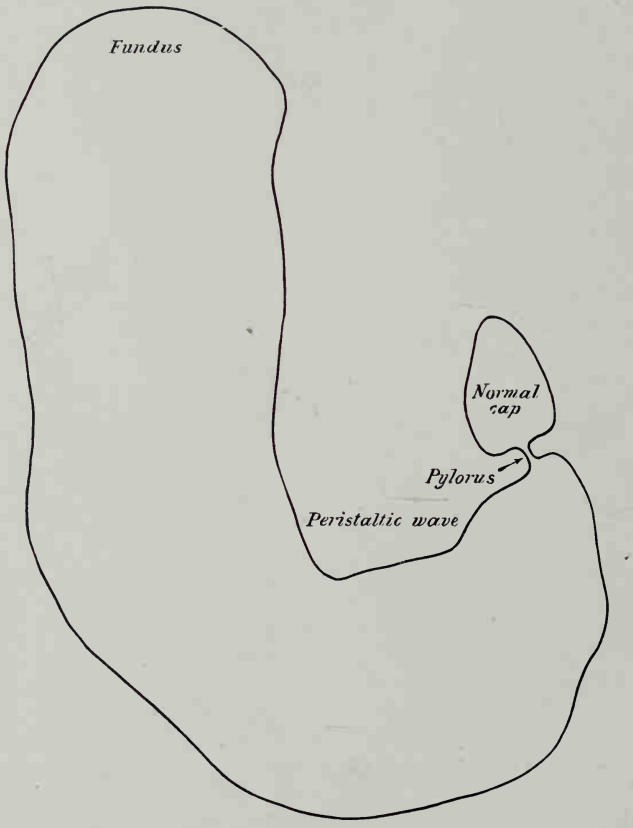

FIG. 139.—Tracing of normal stomach.

at the same time. They are increased in number and depth in the prone position and may be strongly affected by mental states, being increased by rage or inhibited by fear or nausea.

Changes in Size.—The stomach is increased in size when dilatation has occurred as a result of pyloric obstruction or in conditions where there is a general loss of muscle tone. It is diminished

in size (1) as a result of increased tone from strong muscular development or as a reflex from disease of the duodenum, gall-bladder or appendix, and (2) as a result of infiltration of the wall as seen in ulcer, carcinoma, adhesions, syphilis and linitis plastica.

Changes in Position.—The stomach is displaced upward and to the right where there are adhesions to the liver as a result of gall-bladder disease or from the presence of a large accumulation of gas in the splenic flexure or tumors in the left upper quadrant. In some cases of appendiceal disease or adhesions the lower pole is swung

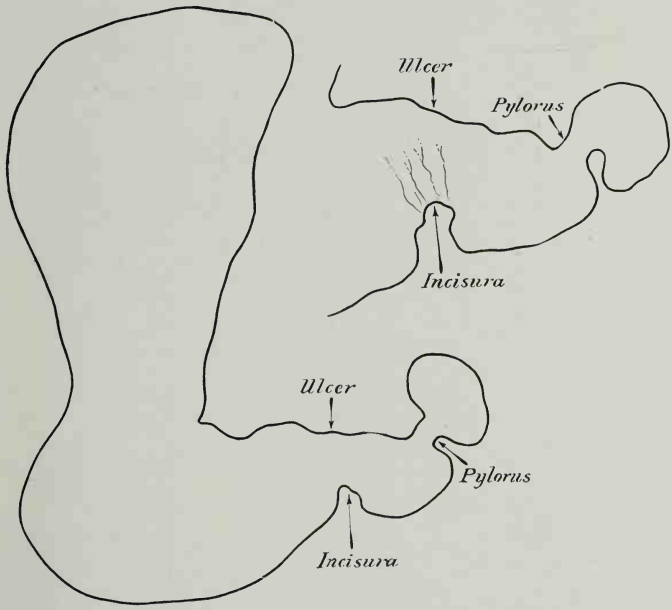

FIG. 140.—Tracing of stomach, showing a small ulcer on lesser curvature near the pylorus. There is no visible crater.

over toward the right iliac fossa. It may be displaced and rotated upward on its long axis in case of adhesions to the anterior abdominal wall. General gaseous distention of the intestine or fluid in the peritoneal cavity crowds the stomach upward against the liver. Displacement downward (ptosis) is of no importance unless accompanied by a six-hour residue or definite clinical evidence of abnormal function. It may be shifted downward and to the left by enlargement of the liver or tumors in the right upper quadrant. In pyloric obstruction where dilatation has occurred the stomach shadow often

appears farther to the right than normal, but this is due to dilatation of the antrum and is not a true displacement of the entire stomach. Very rarely the cardiac end of the stomach will be found to lie above the diaphragm as a result of a congenital or traumatic hernia through the diaphragm. This condition is best seen with the patient supine.

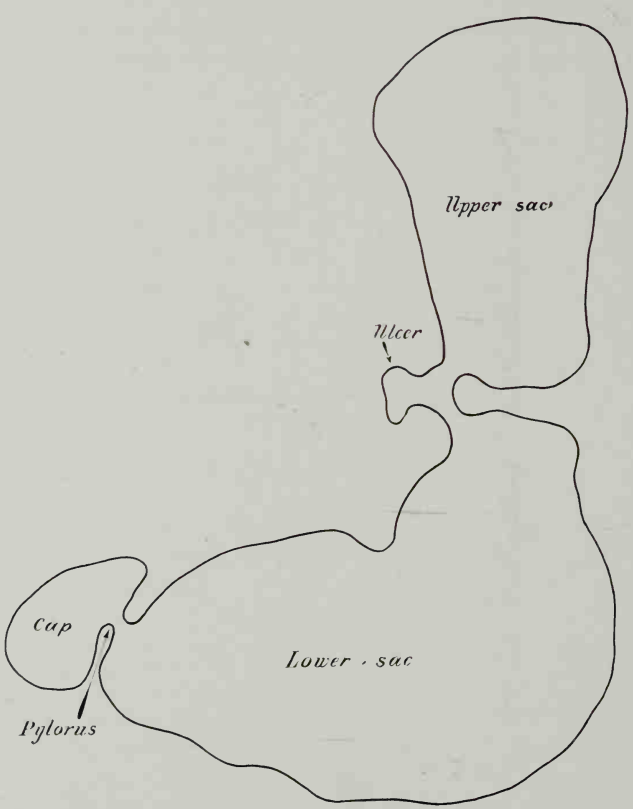

FIG. 141.—Tracing of stomach, showing penetrating ulcer of lesser curvature. Patient prone.

Changes in Outline.—Changes in outline occur (1) as a result of spasm. This may be localized as seen in the narrow contractions near the pylorus or in the upper portion of the body of the stomach where the greater curvature is drawn in toward the lesser over a space of a few millimeters. These spasms may be reflex or be due to the irritation of a small ulcer or new growth at that level. Spasm may also be extensive, obliterating the entire antrum, for example.

Here again it may be entirely reflex or be due to an associated lesion of the stomach wall, which is often a difficult matter to decide. Functional spasms usually are transitory so that repeated observations of the patient will frequently settle the matter. Antispasmodics, such as belladonna or papaverin, may be employed, but they are not conclusive because of the fact that at times they relax

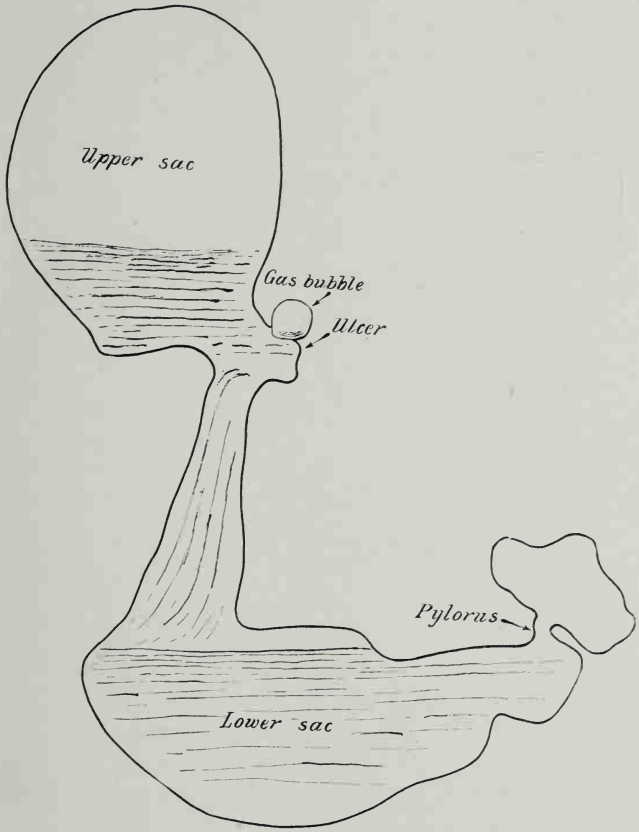

FIG. 142.—Stomach showing penetrating ulcer of lesser curvature. Patient standing.

the spasm associated with a lesion of the wall as readily as those due to functional causes; so that the question of the presence or absence of a lesion must depend upon other evidence than that of spasm. (2) As a result of gastric lesions. Under this heading come the contracted, rigid, smooth lesser curvatures with absence of peristalsis seen in ulcer and carcinoma; the presence of the

crater of a penetrating or perforating ulcer projecting from the gastric outline on the lesser curvature or posterior wall; marked irregularities of carcinoma which vary according to the size, shape and position of the tumor. These deformities are usually either annular or due to the presence of irregular masses invading the barium mixture, leaving ragged holes or markings suggesting finger prints. We may also have the local contractions due to an ulcer

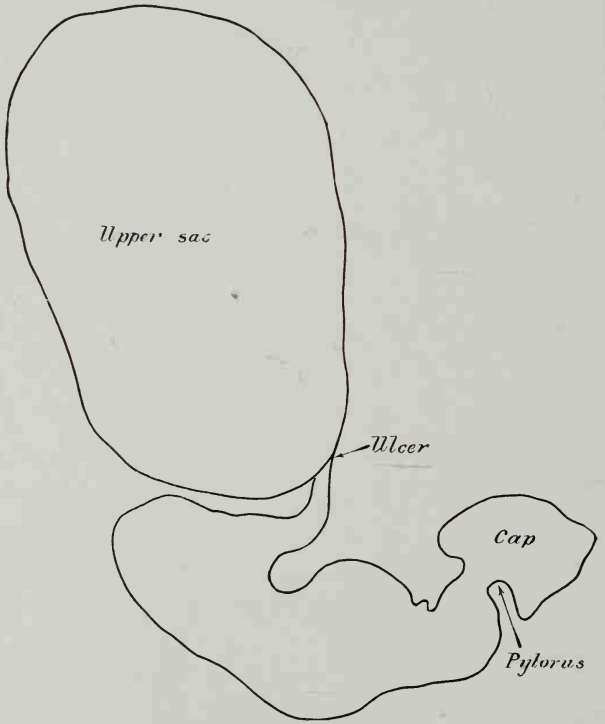

FIG. 143.—Tracing of stomach, showing large ulcer on lesser curvature.

with its associated spasm; or the extensive defects of lues, suggesting ulcer or carcinoma. Another deformity is that which occurs as the result of contraction of scar tissue in the gastric wall, producing a so-called hour-glass stomach. This deformity is constant in all positions. (3) Defects due to extragastric causes such as tumors; or pressure as, for example, the gall-bladder which produces a rounded depression in the region of the pylorus, or pancreatic tumors which cause irregularity of the greater or lesser curvature.

These are not constant in all positions of the patient. An enlarged liver may cause defect in the antrum by compressing it against the spine. In plates taken in the prone position the pressure of the spine against the abdominal wall commonly causes a break in the barium shadow overlying it. Perigastric adhesions, particularly those

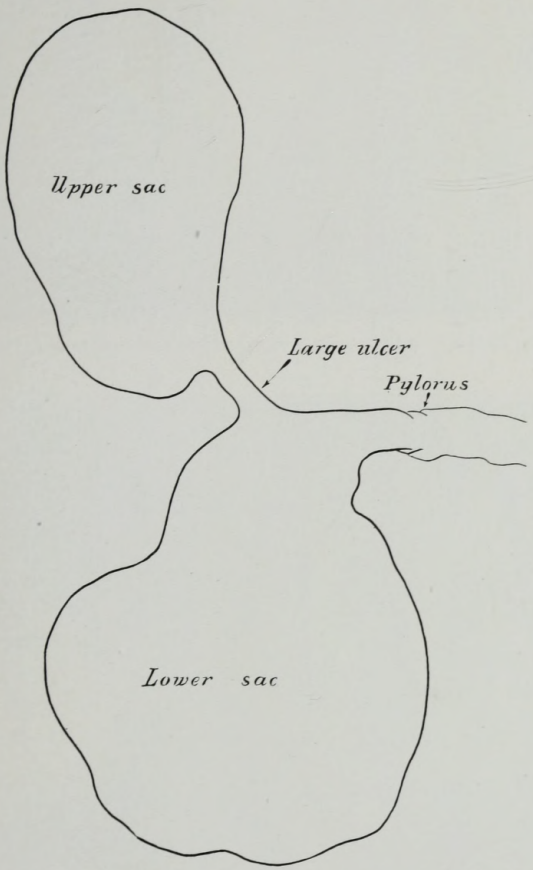

FIG. 144.—Tracing of stomach, showing large saddle ulcer.

about the pyloric end of the stomach, may produce ragged defects suggesting carcinoma but as a rule they are not constant in all positions. (4) Any solid material in the stomach, such as food masses, foreign bodies, hair balls, and the like, may cause defects in the barium mass resembling malignant disease. However, these irregularities shift with changes in position of the patient and there

is no interference with peristalsis. Papillomata produce defects similar to those seen in large foreign bodies, but there is little displacement of the defect with change in position of the patient, peristalsis is not interfered with, and they are constant on repeated examinations.

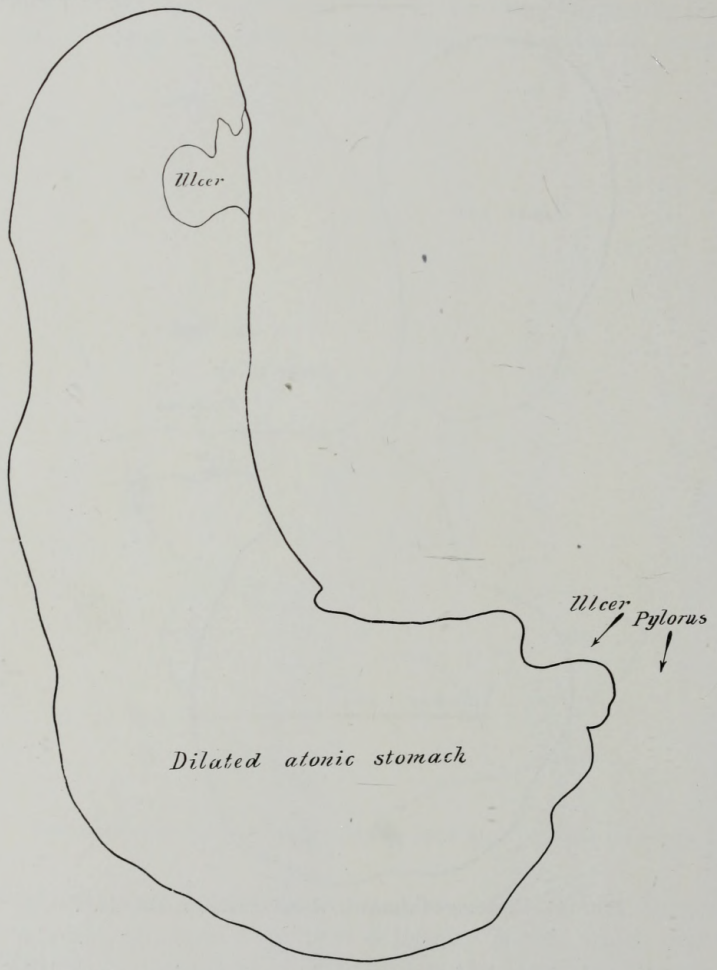

FIG. 145.—Tracing of stomach, showing ulcer at fundus and large ulcer of the lesser curvature involving the pylorus.

Changes in Peristalsis.—Increase in the depth or speed of waves may be due to reflex or irritative causes or compensatory to a diseased pylorus. In the early stages of pyloric obstruction the

FIG. 146.—Penetrating ulcer of the lesser curvature and ulcer of the duodenum.

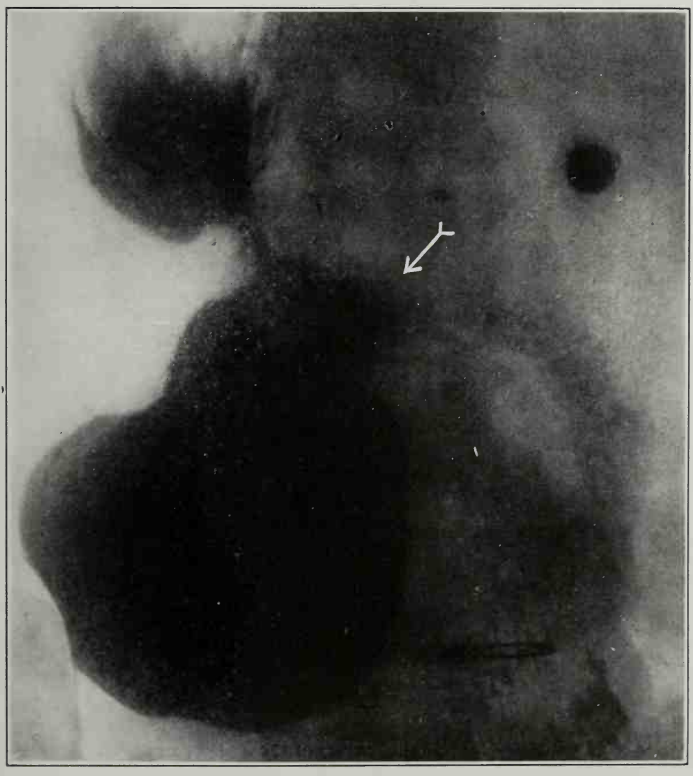

FIG. 147.—Large saddle ulcer causing hour-glass stomach.

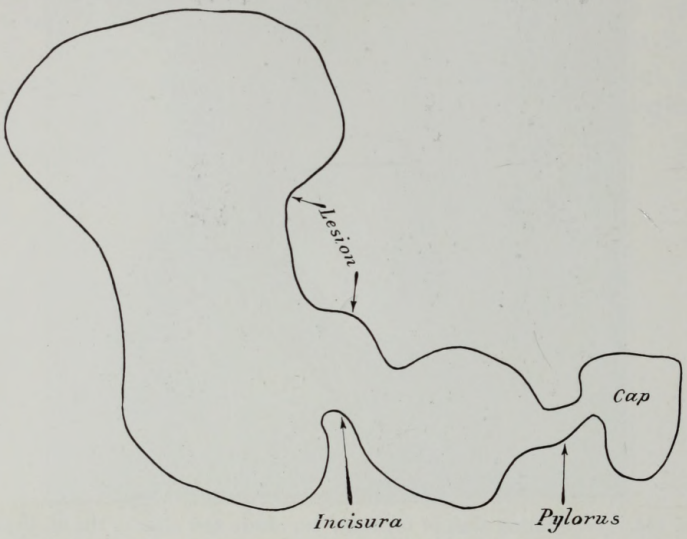

FIG. 148.—Cancer high on the lesser curvature. Note the large area involved and the absence of a definite projection.

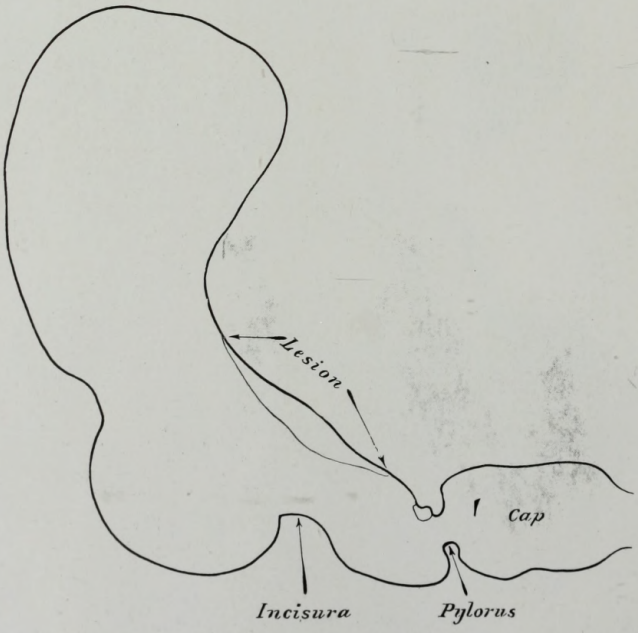

FIG. 149.—Malignant disease of the lesser curvature.

waves are deep and vigorous. They may bisect the stomach, giving it the appearance of a row of balls. The waves also start higher and more are visible at the same time. Peristaltic waves are lost in achylia, in the stage of decompensation of pyloric stenosis, in infiltration of the gastric wall, and in nausea, fear or faintness. They are irregular where they encounter areas of infiltration in the gastric wall or strands of adhesions and possibly in some functional disturbances. Peristalsis may be reversed in carcinoma and tabes.

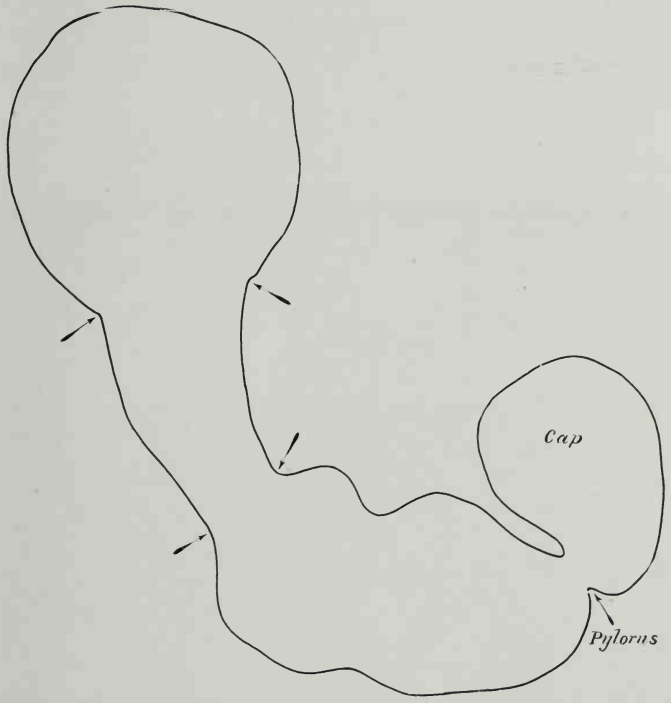

FIG. 150.—Tracing of the stomach, showing annular constriction of the media due to cancer.

Motility.—The normal stomach empties in three to six hours, depending upon the amount and composition of the meal, the tone of the stomach and its functional activity, If it empties in less than three hours, achylia, an incompetent pylorus, duodenal ulcer or gall-bladder disease is suggested. If there is a definite residue (one-quarter of the original meal) beyond six hours and the patient has taken no food in the meantime, one must suspect a lesion

in the stomach, reflex irritation of the pylorus (duodenum, gall-bladder, appendix) or obstruction in the intestine below. In rare instances delay may be due to acute illness, marked ptosis or the action of certain drugs.

Carcinoma.—Because of the insidious onset of carcinoma, the patients do not appear for examination until there is a well-established lesion so that few early ones are found. The characteristic findings are defects in outline, absent, sluggish, irregular or reversed

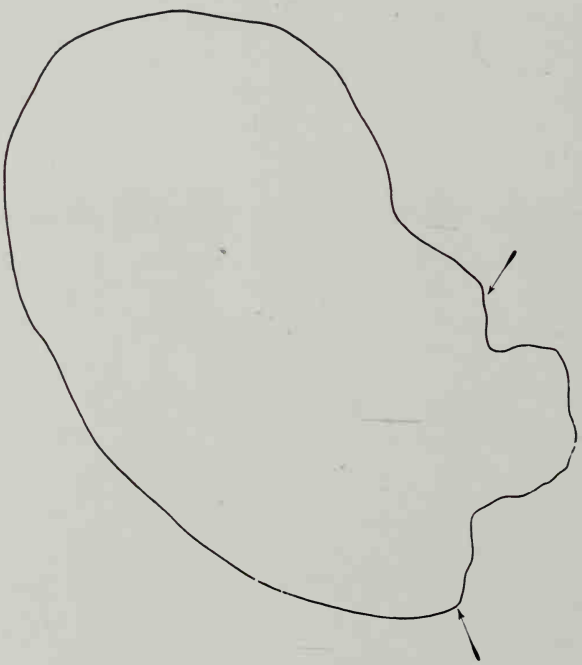

FIG. 151.—Extensive malignant disease of the media and antrum.

peristalsis, esophageal or gastric stasis (or early gastric emptying) and loss of flexibility of stomach wall. The appearances seen vary considerably with the type of growth and with its location. Carcinoma of the cardia is often difficult to visualize. In these cases it is helpful to watch the first mouthfuls of barium entering the stomach. The jet will be irregular instead of smooth and there may be delay at the cardia. There will also be rigidity and deformity of the fundus which does not change on deep inspiration. For this observation the patient should lie on his back.

Large growths in the body and antrum are usually characteristic. There is a ragged annular defect which is constant at all times and in all positions. If the tumor is palpable it will be found to coincide

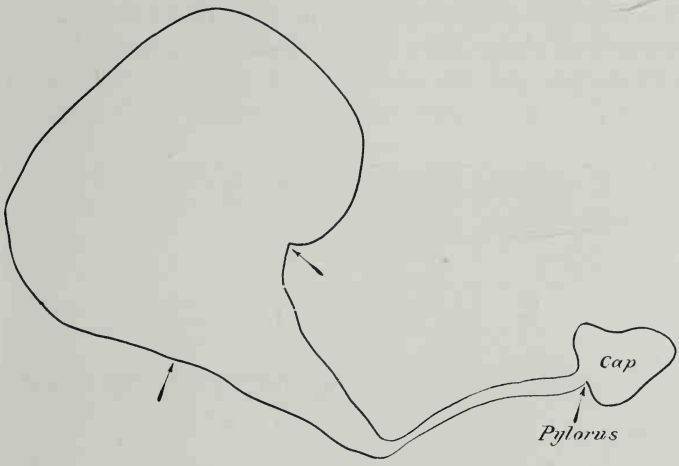

FIG. 152.—Extensive annular involvement of the media and antrum due to malignant disease.

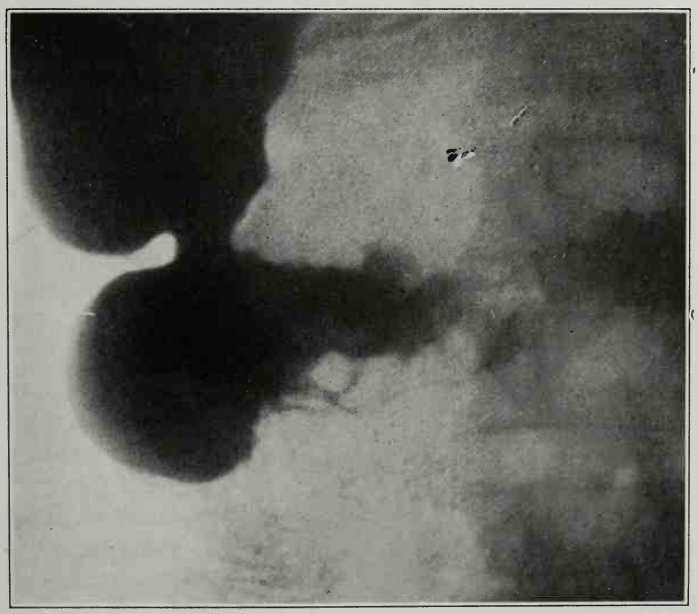

FIG. 153.—Malignant disease of the pyloric end of the stomach.

with the defect. Peristalsis is absent in the region of the growth and may be irregular, sluggish or reversed elsewhere. Stasis is usual. The differentiation is from ulcer, lues, adhesions and extragastric tumors. Typical ulcers and typical carcinoma are easily distinguishable but borderline cases are often hard to identify. Carcinomatous ulcers may, like benign ulcers, be limited to one wall and show a rigid area of infiltration with the pocket of a crater projecting from it. However, the crater is usually larger in car-

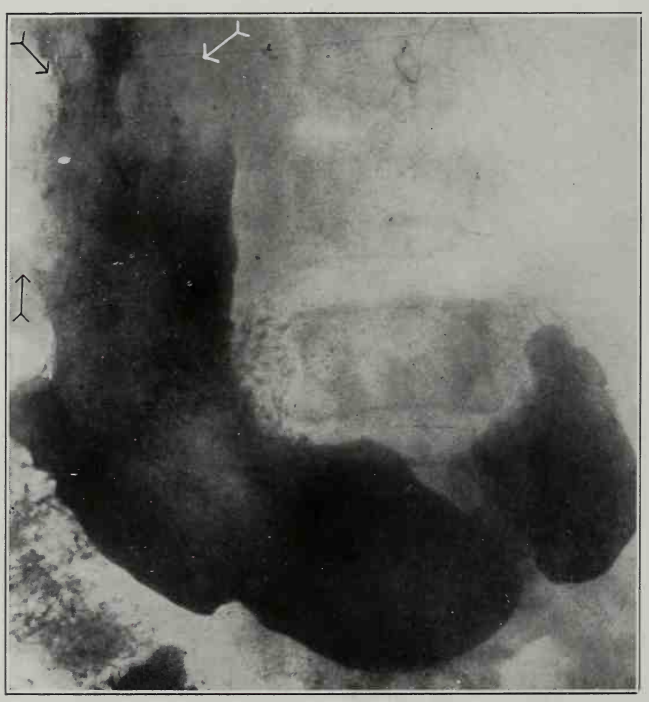

FIG. 154.—Malignant disease of the cardia, with metastasis in the lungs.

cinoma and peristalsis will be diminished or irregular, while in ulcer it is apt to be increased. Stasis may occur in both cases but is perhaps more frequent in ulcer. Spasms and incisuræ are much more common in ulcer.

In lues the deformity is generally more irregular and the patient is in better condition than he would be with a carcinoma of similar extent. The defect is out of proportion to the symptoms.

The defects in adhesions and extragastric tumors are usually not constant in all positions and stasis is generally absent.

Diffuse infiltration of the stomach wall occurs in scirrhous carcinoma, lues and linitis plastica (which may be one form of lues). The signs are those of infiltration—a smooth, rigid outline with absence of peristalsis and usually a contracted, rapid emptying stomach.

Pyloric Carcinoma.—In well-established cases there is a definite funnel-shaped defect and if the pylorus is involved, the outlet becomes rigid and the stomach may empty rapidly. Dilatation of the stomach is rarely present. In early carcinoma at the pylorus there may be a funnel-shaped defect which is not due to the actual lesion, probably as a result of associated spasm.

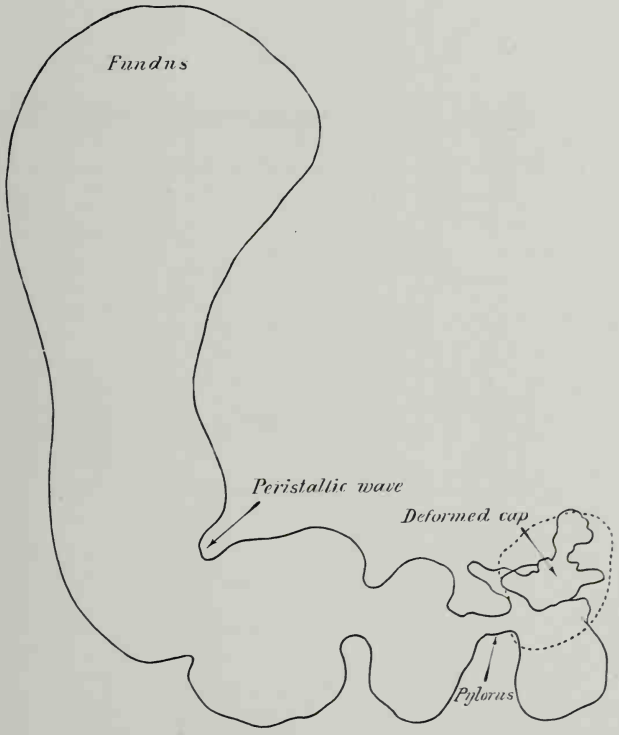

FIG. 155.—Tracing of stomach, showing typical deformity of cap due to duodenal ulcer.

Ulcer.—In general, ulcers are more readily found the closer they are to the pylorus. Stasis is of more significance the nearer the lesion lies to the sphincter, *i. e.*, if there is pyloric deformity and no residue, it is not due to ulceration but to some other condition, most

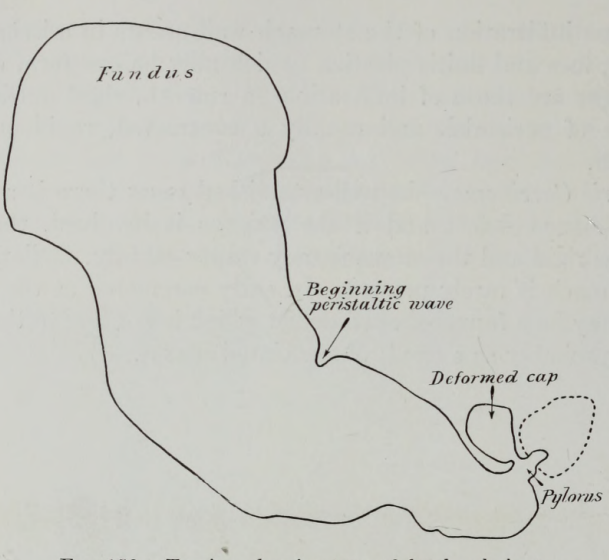

FIG. 156.—Tracing, showing type of duodenal ulcer.

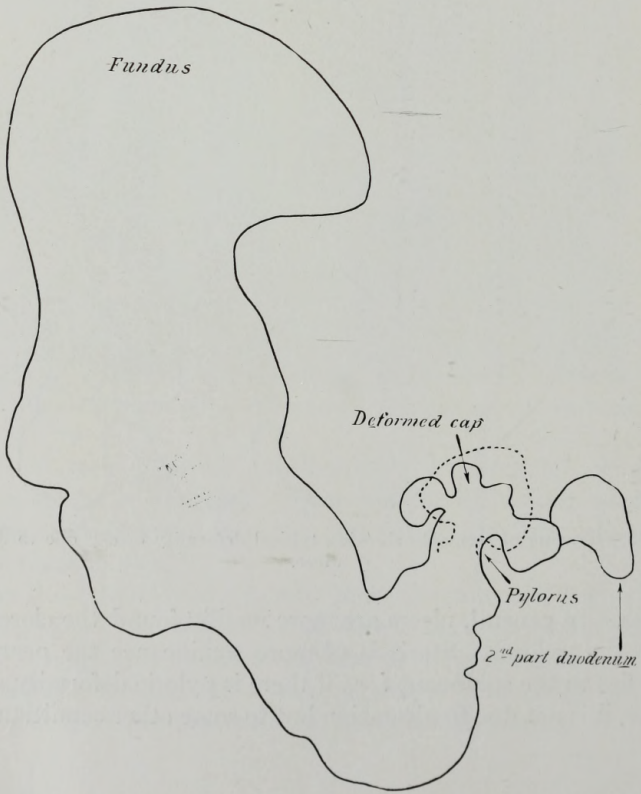

FIG. 157.—Tracing, showing type of duodenal ulcer.

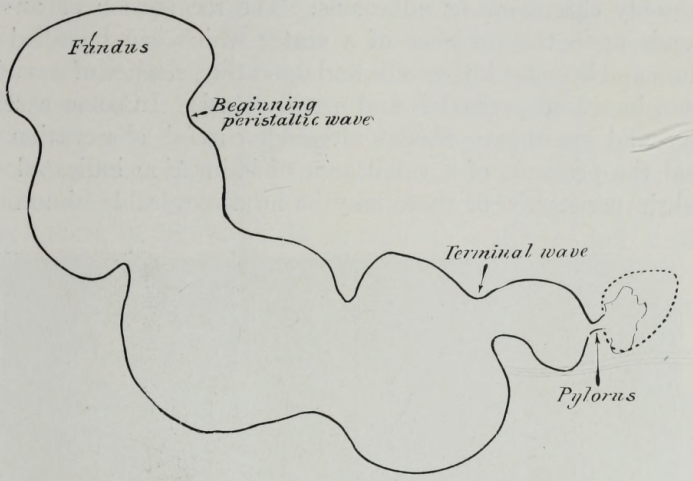

FIG. 158.—Tracing of stomach, showing the deep, vigorous peristalsis of duodenal ulcer.

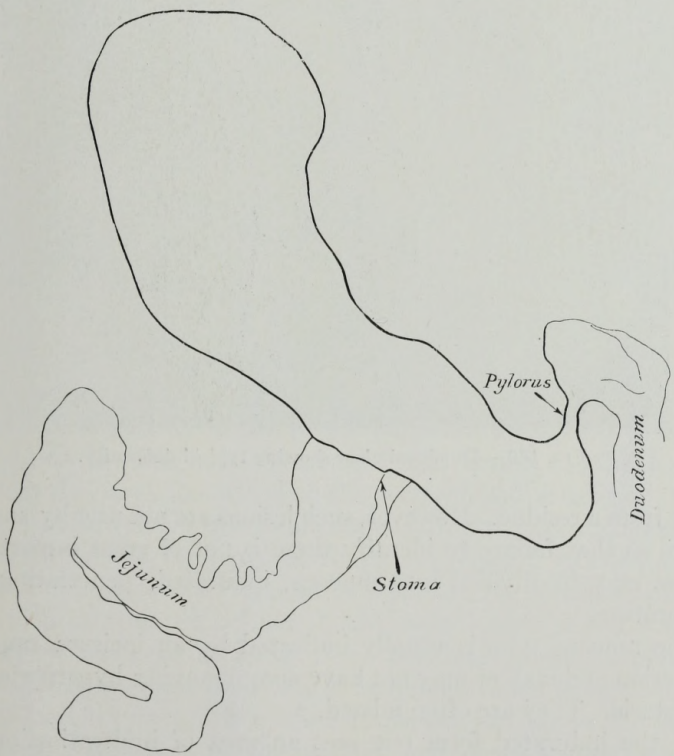

FIG. 159.—Tracing of the stomach, showing stoma and position of bismuth in small bowel after gastro-enterostomy.

commonly carcinoma or adhesions. The recognition of an ulcer depends upon the presence of a crater which can be filled with barium and brought into profile and upon the presence of associated spasm, increased peristalsis and usually stasis. In some cases the crater and spasm are absent although careful observation may reveal the presence of a small area of induration indicated by a break in peristalsis, or there may be no discoverable abnormality

FIG. 160.—Duodenal ulcer showing typical deformity.

aside from a residue. However, such lesions are not usually surgical ulcers so that failure to identify them is not of great importance. Ulcers may be divided into mucous, indurated, penetrating and perforating.

The mucous type is usually indicated by an incisura opposite the lesion and may or may not have accompanying hyperperistalsis and stasis. They are often missed.

In the indurated form one sees an area of infiltration on the

lesser curvature which, if extensive, may cause considerable shortening of this curvature. There will be a break in peristalsis at the site of the lesion, hyperperistalsis and stasis. Spasm is not usually present. When it does occur it takes the form of local incisuræ opposite the active edge. Such ulcers may cause irregularity of the greater curvature from contraction of scar tissue which extends out around the body of the stomach. If they occur near the pylorus there is failure of the antrum to contract and stasis is marked. The first swallow of barium may collect in a small pool at the site of the lesion due to the slight spasm which holds up its progress at first but which disappears as the stomach fills.

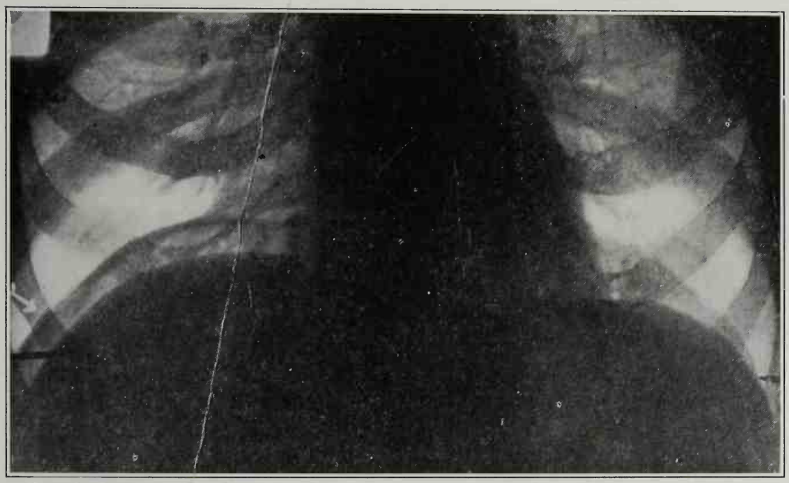

FIG. 161.—Free gas between the upper surface of the liver and the diaphragm following perforation of a duodenal ulcer.

Penetrating ulcers have all the signs of the indurated form and, in addition, a mass of barium projecting from the rigid area which corresponds in size and shape with the crater of the lesion. Although they are often found on the posterior wall surgically, they usually appear on the lesser curvature during the roentgen examination. A lateral view may at times be necessary to adequately visualize these lesions and should be a part of the routine examination which as a matter of fact should include careful observation from every angle in at least three positions—prone, supine or standing. These protrusions must be differentiated from the duodenojejunal flexure which is often projected just above the lesser curvature. Rotation of the patient and deep inspiration will

usually enable one to determine whether or not the mass is actually projecting from the gastric shadow or is independent of it.

Perforating ulcer shows, in addition to the signs of a penetrating ulcer, the presence of a gas bubble outside the stomach wall above the mass in the crater.

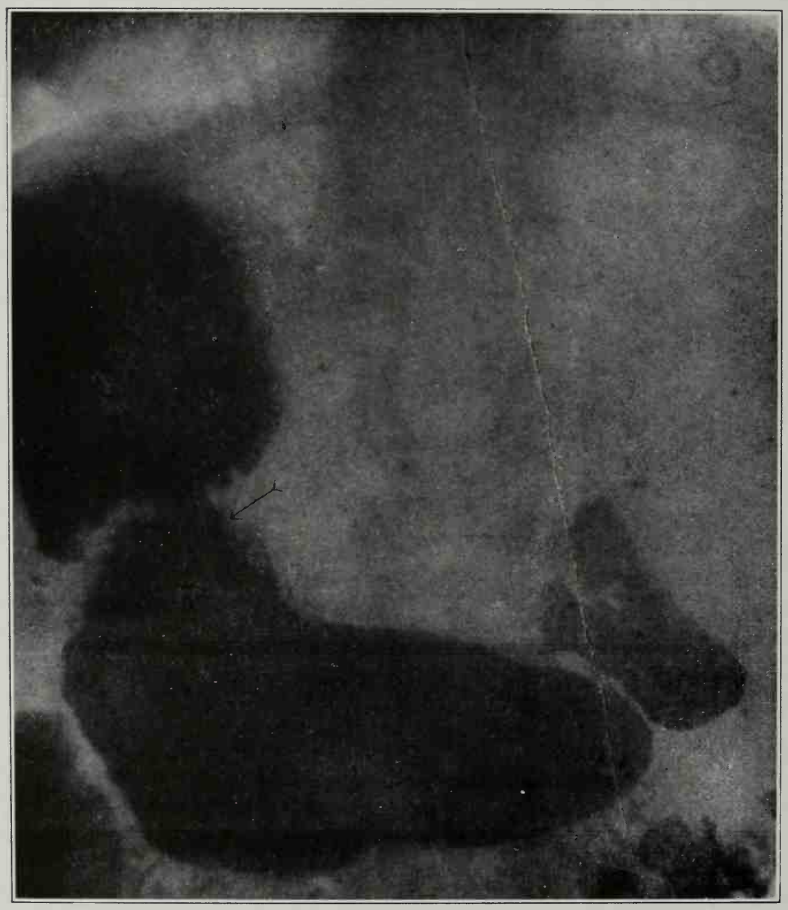

FIG. 162.—Postoperative ulcer of the stomach (recurrent). The constriction is probably the result of the operation. The projection just below it is the crater of a new ulcer.

Syphilis.—Its radiographic appearance is practically that of carcinoma except that mottling of the barium mass and stasis are uncommon. The extent of the lesion is out of proportion to the

patient's symptoms. The age of the patient, the history and the laboratory findings must be relied upon for corroborative evidence. Appropriate treatment improves symptoms and may or may not affect the roentgen picture.

Linitis Plastica.—Linitis plastica is believed by some observers to be a late stage of a luetic process. It is a fairly rare condition in which the gastric wall is infiltrated by dense fibrous tissue which contracts the stomach down to a small, rigid tube high up under the liver, and through which the meal pours in a few minutes.

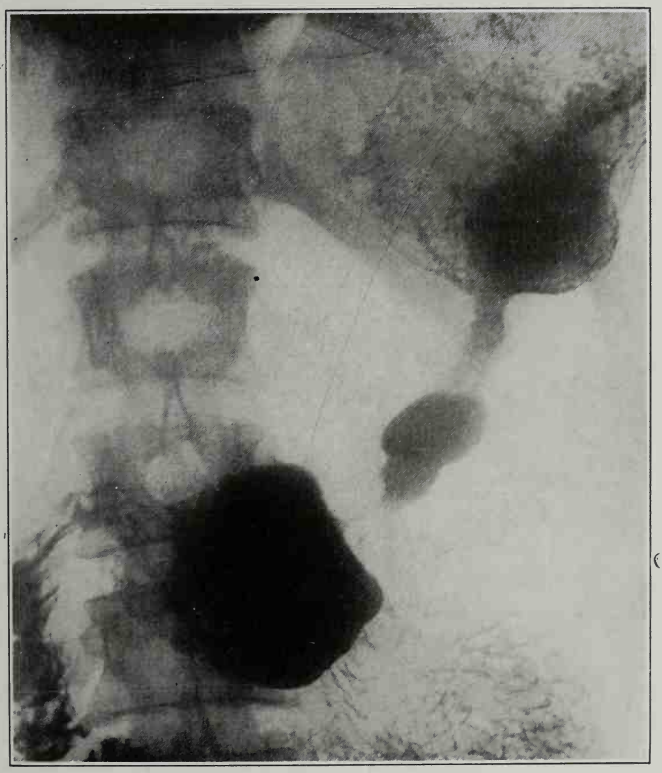

FIG. 163.—Lues of the stomach.

Foreign Bodies.—Hair balls and metal articles are occasionally reported. Whether or not they are in the stomach may be determined by changing the position of the patient, by inflating the stomach with air and the routine barium meal. Hair balls present a characteristic appearance and the barium adheres to them, outlining their structure for some time after the meal has passed on.

Polypi.—Polypi of the gastric wall are comparatively rare. They may be multiple and when demonstrable, appear as smooth, rounded holes in the barium shadow which remain constant with changes in the position of the patient. Peristaltic waves are not interfered with. The condition must be differentiated from foreign materials in the stomach, such as food masses and extragastric tumors. Their constancy is the best evidence. In the late

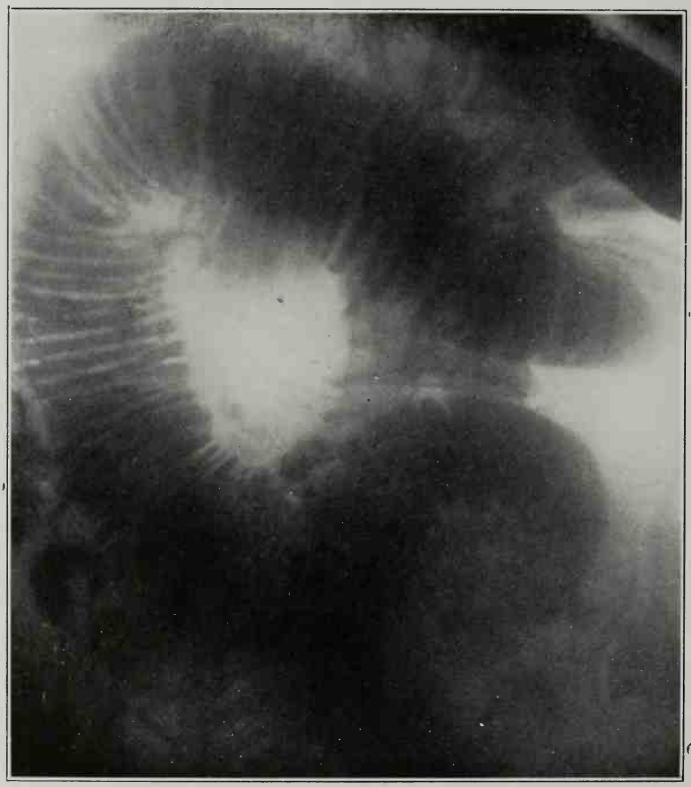

FIG. 164.—Dilatation of the jejunum due to obstruction from malignant disease.

stages, if extensive, they may cause obstruction and be mistaken for malignancy. There is a rare form of polyposis in which an area of the gastric wall is occupied by a mass of hypertrophic tissue which causes a ragged defect simulating carcinoma.

Postoperative.—The stomach after gastro-enterostomy is usually smaller and higher. It empties rapidly, depending somewhat upon the size of the stoma. There is little peristalsis visible. When seen

it usually passes over the entire lower part of the stomach to the pylorus, forcing the barium mixture through unless it has been closed at the operation or by disease. Usually the stoma can be demonstrated and its size, position and contour noted. A loop of the jejunum passing from behind the stomach shadow may lead to errors.

The observations to be made in the order of their importance are emptying time; shape and position of the stoma; type of peristalsis; size of stomach; whether or not food leaves through the pylorus, and the appearance of the duodenal loop.

DUODENUM.

The normal first part of the duodenum is a smooth, rounded, triangular shadow, at times connected with the stomach by a thin line of barium in the pyloric canal when the sphincter is open. Its relation to stomach, gall-bladder and liver varies with the type and position of the patient and the size and shape of the stomach and liver. It has a peristalsis of its own and its filling and emptying are controlled both by the pyloric sphincter and a constrictive action of the junction of the first and second portions. The rapidity of filling and emptying depends largely upon the character of the meal, being much more rapid in the case of watery and carbohydrate mixtures than when proteins are present. It may be considerably enlarged in atonic individuals. Enlargement may also occur as a result of adhesions or bands about the duodenum or ulcer of the second portion. It may be contracted as a result of spasm, scar tissue in the wall or adhesions about it. Defects in outline may be due to pressure as, for example, smooth rounded depression due to the gall-bladder and the small indentation on the inner margin due to the bile duct. Scars and the spasm from ulcers cause irregular deformities which produce the familiar coral-shaped shadow. Rarely, as a result of perforation of such an ulcer, there may be a pocket filled with barium between the duodenum and the liver or colon. In some cases of perforation, free gas has been demonstrated in the peritoneum above the liver. Adhesions usually produce slight irregularities which are not constant. Spasm may produce extensive changes in the shape of the duodenal bulb. It is usually reflex from a lesion of the gall-bladder or the appendix. Very rapid emptying where the meal shoots through the cap rapidly is seen in gastric, pyloric and duodenal ulcer. Delayed emptying may be due

to obstruction in the duodenum or the intestine lower down, but usually occurs reflexly as a result of gall-bladder or appendiceal disease.

Ulcer.—The signs of ulcer are deformities in outline, changes in motility already mentioned, in addition to changes in gastric peristalsis and motility. The deformities in outline must be differentiated from those due to spasm as a result of gall-bladder or appendix. The deformity of ulcer is constant, whereas that due to spasm will vary or disappear at different examinations. It is probable that a part of the deformity seen in duodenal ulcer is due to local spasm accompanying the lesion.

Adhesions.—Adhesions may produce slight irregularities in the cap which are not constant with change in position of the patient and there is usually fixation of the bulb. Constricting bands may be found anywhere in the course of the duodenum. Evidence of their presence is seen in dilatation and delay in motility, a common form of which is the pendulum movement of masses of barium to and fro in the second and third portions. Normally the meal passes as a flocculated mass through the second and third portions of the duodenum with considerable rapidity so that they are less well outlined than the first portion. The entire second and third portions are well outlined only when there is a rapidly emptying stomach or in cases of obstruction from adhesions or pancreatic disease. Delay in any portion of the duodenum, pendulum movements of the barium mass, visible and reverse peristalsis are suggestive of spasm or obstruction, although vigorous pressure upon the epigastrium in an attempt to fill the cap will cause delay, dilatation and reversed peristalsis. Ulcer is rare in this region although craters have been seen. The ampulla of Vater may be dilated and appear as a definite spot of barium a few millimeters in diameter along the descending portion. Diverticula are occasionally seen. They appear as rounded masses in close proximity to the duodenum. Duodeno-gall-bladder fistulæ have been demonstrated and in rare cases the barium meal may outline an enlarged common duct.

JEJUNUM.

The jejunum normally appears as coils of fine, feathery flakes of the meal due to the rapidity of its progress. It is never outlined except in pathological conditions, the most common of which are peritonitis, acute or chronic, and obstruction from bands or tumors.

A tumor sufficient to cause obstruction is nearly always palpable. In peritonitis and obstruction the flocculent appearance is lost and the coils are dilated. Gastrojejunal ulcer may occasionally be made out at the site of gastro-enterostomy. The diagnosis is based upon a persistent irregularity in outline (often difficult to visualize) in the region of the stoma; changes in gastric peristalsis; a gastric residue beyond six hours, and the clinical picture.

ILEUM.

The normal ileum is seen as a coil of intestine containing dense masses of barium lying low in the pelvis with a loop running up to terminate in the cecum. Palpation is unsatisfactory except in its terminal portion owing to its depth in the pelvis. It is smooth in outline with transverse contractions which are continually changing. It may begin to fill within an hour after the meal has reached the stomach and is entirely emptied by eight to ten hours after a meal. The head of the meal should have passed through it at six hours. Dilatation occurs as a result of obstruction from adhesions or bands. Disease in the ileocecal region usually causes fixation and tenderness of the terminal ileum. A delay of over six hours in entering the cecum or beyond ten hours for complete emptying of the ileum is suggestive of disease in the ileocecal region, in which case there is usually an associated fixation and tenderness of the terminal ileum.

APPENDIX.

The normal appendix fills and empties during the presence of barium in its vicinity and should be visible if persistently and carefully looked for. It is freely movable and not tender and should be empty when the cecum has emptied. It may present one or more constrictions which are without significance. When it is or has been the seat of disease, it either never fills or fills irregularly and contains a residue after the cecum is empty. There may also be tenderness and fixation of cecum and terminal ileum, stasis in the ileum, stasis and hyperperistalsis in the stomach, spasm of the duodenum, and at times stasis in the tip of the cecum after a meal and after enema. An incompetent ileocecal valve is often associated with such an appendix. Stones and foreign bodies are sometimes demonstrated in appendices and may be mistaken for ureteral stones.

CECUM.

The normal cecum is smooth with transverse constrictions and is freely movable vertically and laterally but varies greatly in size, position and mobility. A filled terminal ileum is often necessary to identify it positively. It may be dilated in cases of obstruction in the distal colon or in spastic constipation. It may be contracted by extensive adhesions about it. Changes in outline which are best demonstrated by enema are due to adhesions, to carcinoma which produces large, irregular defects, or to inflammatory masses as a result of tuberculosis or a chronic appendix, which may produce large defects resembling carcinoma, but careful observation will usually show them to be outside the colon. Tuberculosis of the cecum produces a local irritation such that the barium meal or enema never remains at the site of the lesion. A typical finding is stasis in the ileum at six hours and an empty ascending colon at twenty-four hours. An enema reveals either defects in outline or a failure to fill at the site of the lesion. The normal cecum is never empty when barium is present in both ileum and ascending colon.

COLON.

The colon varies greatly in size and position from hour to hour and in different individuals. The outline is smooth and broken by haustral segmentations. The meal normally reaches the splenic flexure in twelve to eighteen hours and the colon is entirely clear in from twenty-four to seventy-two hours. Movements of the colon are: (1) haustral churning, that is, formation and reformation of haustral contractions and (2) antiperistalsis or anastalsis. A contraction ring exists at about one-third of the distance between the hepatic and splenic flexures and from this point antiperistaltic waves run slowly backward to the cecum. (3) Pendulum movements where large masses of contents swing back and forth through short distances, they are usually soon followed by (4) mass movements where haustral markings disappear and large masses of barium are rapidly propelled through a considerable portion of the colon. In outlining the colon by enema it takes a few minutes to complete the filling of the rectum and sigmoid, after which the fluid should run over readily to the cecum. The pelvic loop of the sigmoid as it distends should rise well out of the pelvis. If it is retained in the pelvis, pelvic adhesions should be suspected.

Variations.—The position of the colon may be reversed so that the ascending colon lies on the left side in cases of transposition of viscera and it may not rotate completely during the process of development, or the ascending colon may not be completely formed so that the cecum lies in the region of the gall-bladder. The sigmoid is subject to great variation in length and amount of omentum. In cases of so-called redundant sigmoid it may be found anywhere in the abdomen.

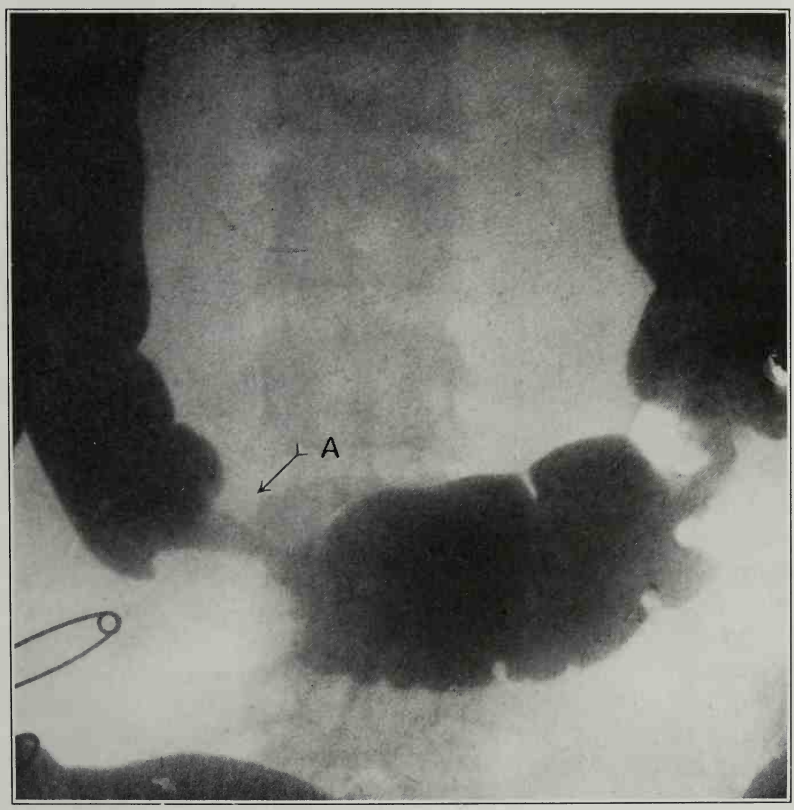

FIG. 165.—Carcinoma of the transverse colon at *a*. On the opposite side there is a narrowing of the gut, due to spasm.

Changes in Size.—The colon may be dilated as a result of congenital malformations, so-called megacolon or Hirschsprung's disease, or as a result of obstruction from bands or tumors. The caliber of the transverse and descending portions is uniformly diminished in spastic constipation.

Changes in Position.—Changes in position are not important unless they are permanent and fixed as, for example, sigmoid to the gall-bladder region or the appendix region.

Changes in Outline.—In observations after barium meals the colon will often show irregular defects due to the presence of fecal matter. They are not permanent and in case of doubt an opaque enema will rule out pathology. Defects are seen best after enema. The common ones are the annular, ragged, funnel-shaped deformities due to carcinoma and the constrictions caused by bands of adhesions. Multiple small buds are sometimes seen along the course of the colon, particularly in its descending portion, which represent barium-filled diverticula. They may be overlooked if the only observation of the colon is twenty-four hours after the meal. The barium-filled colon may overlap and obscure them so that where their presence is suspected the patient should be seen after the colon is empty, as small residues may remain in the diverticula for several days after the colon is clear, in the form of small, round, dense masses scattered along the course of the colon. They are sometimes brought out by an enema when a meal has failed to reveal their presence. It has been noted that there is a complete absence of segmentation in severe cases of colitis.

Change in Motility.—Decreased emptying time occurs in achylia, in conditions which produce a rigid, incompetent pylorus, and in colitis. Increased emptying time or constipation appears usually in three forms, spastic, atonic and rectal. The spastic type is the result of increased tone of the transverse and descending colon shown by a diminution in caliber and changes in haustral segmentations which are fewer in number and increased in width. The delay in these cases may be extreme, barium remaining in the colon as late as a week after the meal. The atonic type is characterized by a large, flabby colon and is comparatively rare. It may be seen in asthenic states where there is a general loss of tone. In the rectal type there are large masses of barium high up in the rectum and sigmoid occupying most of the pelvis. There is, of course, more or less delay in cases of obstruction due to adhesions or malignancy.

In acute intestinal obstruction plain plates of the abdomen without barium will often reveal loops of gas dilated intestine above it, which by their character and position determine the site of the lesion.

If the small intestine is affected the coils will occupy most of the abdomen and their margins show the fine markings characteristic

of the small intestine, while if the colon is involved the loops are larger, smoother and have a few haustral segmentations. The dilatation ordinarily ends abruptly at the obstruction.

RECTUM.

The rectum appears as a smooth, S-shaped mass, occupying a considerable portion of the pelvis. Defects in outline are due to carcinoma which show the ragged, annular lesions typical of the disease. Ulceration due to lues or tuberculosis may be evidenced by more or less infiltration of the wall which becomes rigid. The diameter of the intestine is diminished rather uniformly throughout the area of the lesion. Pressure from inflammatory masses or tumor in the pelvis may deform or displace the rectal shadow.

FIG. 166.—This plate shows a fairly typical group of gall-stone shadows.

GALL-BLADDER.

Visualization of the gall-bladder is a matter of thorough, careful technic and a certain amount of luck. The patient must suspend respiration completely and the exposure and position of the central ray may be just right for the particular patient. It is an exaggera-

tion to say that every gall-bladder which can be visualized is pathological. However, it is undoubtedly true that a large proportion of pathological gall-bladders can be visualized by careful work. The shadow of the gall-bladder is rounded and sharply margined; it varies greatly in size and position; it may be found anywhere

FIG. 167.—The indefinite ring-like shadow between the eleventh and twelfth vertebræ is that of a single large gall-stone.

from the costal margin to the crest of the ilium. Gall-stones may be recognized if they contain a sufficient amount of calcium salts, which unfortunately is true in only 20 to 25 per cent. of the cases. They appear as single or multiple shadows which may be the typical faint ring, a dense homogeneous mass, or a mottled area of density due to many small stones packed together. Great care

must be taken to resist the tendency to make positive diagnoses of gall-stones from any faint shadows in the gall-bladder region. Shadows of stones are often very faint but they at least should show definite rings and lie entirely within the limits of the gall-bladder before they can be diagnosed as stones. The proper significance of the negative diagnosis should be realized and insisted

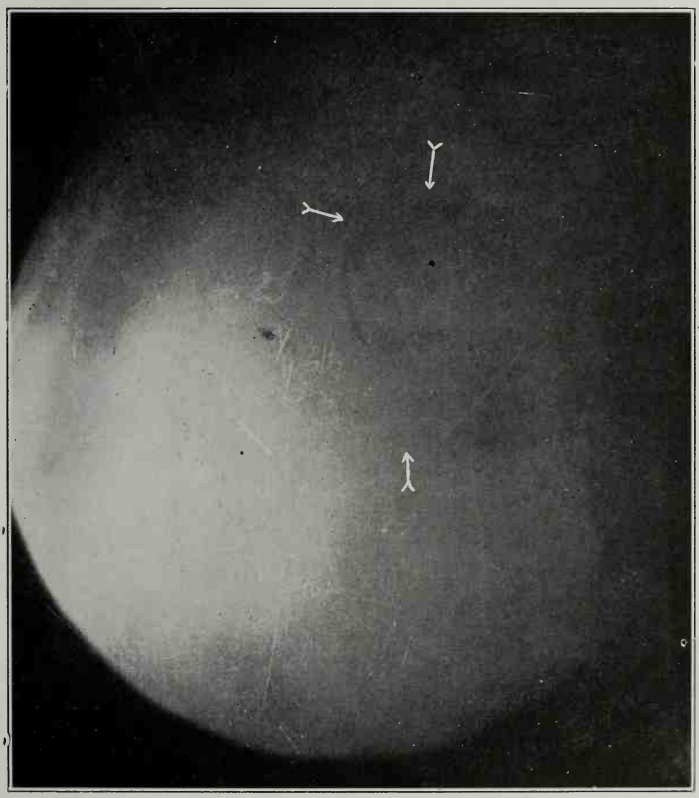

FIG. 168.—The large indefinite shadow near the spine is not a gall-stone, as nothing was found at operation. It is probably a retroperitoneal gland.

upon at all times. A negative diagnosis is of no positive value, for stones may be present and cast no shadow. Furthermore, the patient's symptoms may be due more to associated pathology in the gall-bladder than to the stones. Patients occasionally refuse a needed operation because stones have not been demonstrated by the roentgen method. They should be warned in the beginning that gall-stones may not show. When gall-bladder disease is suspected

a routine gastro-intestinal examination should always be done to determine the incidence of adhesions and reflex gastric disturbances such as spasm or stasis.

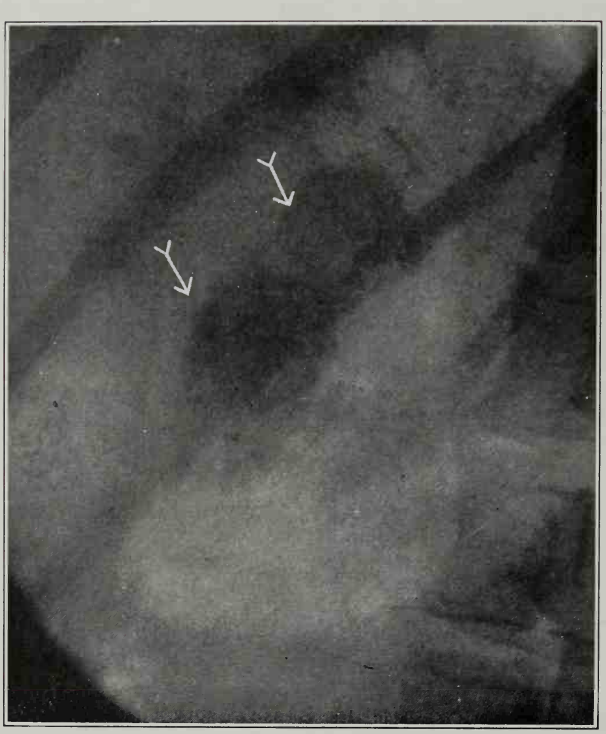

FIG. 169.—Calcified retroperitoneal glands resembling a gall-stone.

Pneumoperitoneum.—Inflation of the peritoneal cavity with various gases is a spectacular means of demonstrating the abdominal viscera, and in selected cases has a definite place in roentgenology. The liver, spleen, kidneys and often the pelvic viscera are brought out with startling clearness. It is particularly useful for the demonstration of adhesions to the abdominal wall and the relations of tumor masses to the abdominal viscera.

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CHAPTER IX.

GENITO-URINARY TRACT.

Preparation of the Patient.—The preliminary preparation of the patient is a matter of opinion. If it is thought advisable, a vegetable cathartic or oil should always be recommended. Mineral salts and enemata are particularly to be avoided, the former because of their tendency to fill the intestine with fluid and the latter because they are seldom entirely expelled and air is usually introduced along with them. Fluid or air in the intestine may entirely obscure the kidneys and cause a confusing shadow. Excellent plates may often be obtained with no preparation.

Technic.—Examinations should always include both kidneys, the course of the ureters and the bladder. Suspicious shadows and most positive findings should be checked up with a second examination on another day. This work requires plates of the best technical quality. Any evidence of respiration or other motion on a roentgenogram should cause its rejection. Plates of the bladder area should be made in both anteroposterior and postero-anterior positions. The ideal plate should be of moderate density, thin rather than overexposed and, as Leonard pointed out long ago, kidney plates should show clearly the last two ribs, the transverse processes of the vertebræ and the margin of the psoas.

THE KIDNEYS.

The *normal kidney shadow* is of the familiar form, in length approximately equal to three vertebral bodies—the twelfth thoracic and first and second lumbar—and of smooth, regular contour. The right lies 1 to 2 cm. lower than the left, and is less frequently seen. Visibility depends upon the amount of fat about the organ and upon technic. Kidneys are somewhat movable in the normal individual. They will drop one or two cm. in the change from the supine to the standing position. In young children they are lower than in adults. They lie close to the margin of the psoas and are crossed by the shadows of the last two ribs.

Changes in size of the kidneys are not diagnostic. The shadow may have been distorted or enlarged by the size of patient or position of tube; or a kidney may be hypertrophied as a result of disease in its fellow, while on the other hand, the shadow may be of normal size but the kidney be badly damaged.

Changes in shape are due to tumors, cysts, infections, and anatomical variations.

Changes in position are occasionally seen. Kidneys may be found in the pelvis, they may fuse across the vertebræ, and there may be only one kidney present.

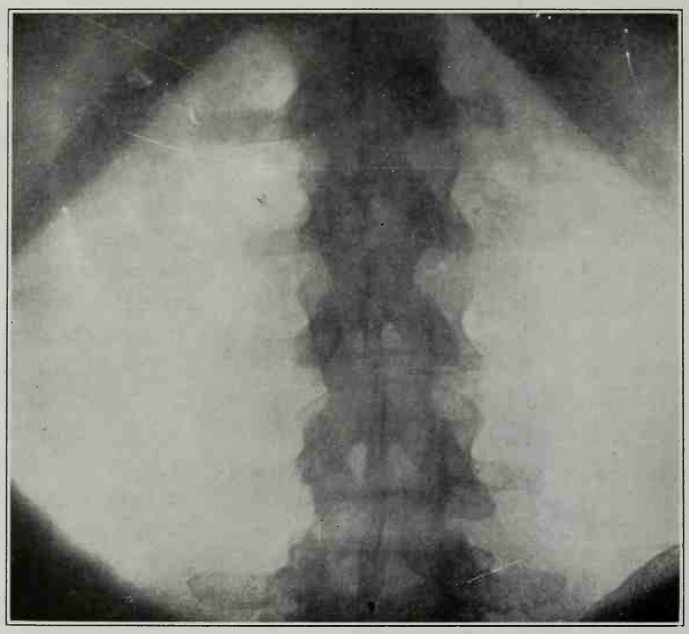

FIG. 170.—Position and outline of normal kidneys, with the patient standing.

Changes in density will be found extremely unreliable in diagnosis. While it is true that in rare cases tuberculosis of the kidney may be suspected from the presence of a mottled shadow of increased density, in general, mottling will be found to be due to intestinal contents. The principal value of the roentgen examination lies in the detection of stone. In good hands, probably 80 per cent. of all kidney and ureteral (not bladder) stones will show. Their visibility depends upon the technic, preparation and size of patient

and the composition and size of the stone. The first two factors may be controlled by repeated examinations and in regard to the last point, the order of visibility is as follows: phosphates and cystine very dense, oxalates next and urates last, which have little if any greater density than that of the soft tissues. Stones which lie in large inflamed kidneys may be so obscured by the general density about them that they are not visible. Furthermore, the shadow of a stone may overlie a rib, transverse process or sacrum

FIG. 171.—Lesion of lower pole.

and be overlooked. It sometimes happens that a stone previously invisible will receive a coating of opaque medium during pyelography and become evident. Stones usually occur in the region of the pelvis and lower calices. They may be round, although they are often irregular and sometimes assume the form of a cast of the pelvis in which they are located. It must not be forgotten that a single shadow may represent multiple stones. Discrete shadows scattered through the periphery of the kidney shadow suggest a

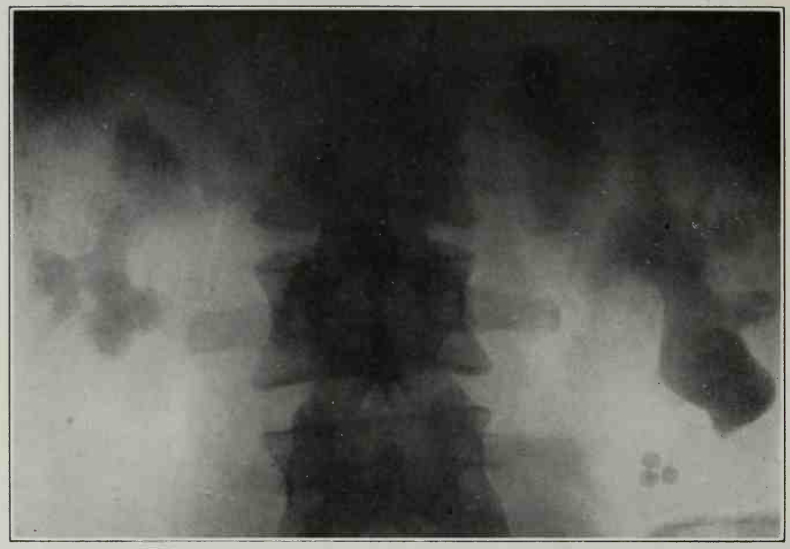

FIG. 172.—Large branching calculi in both kidneys.

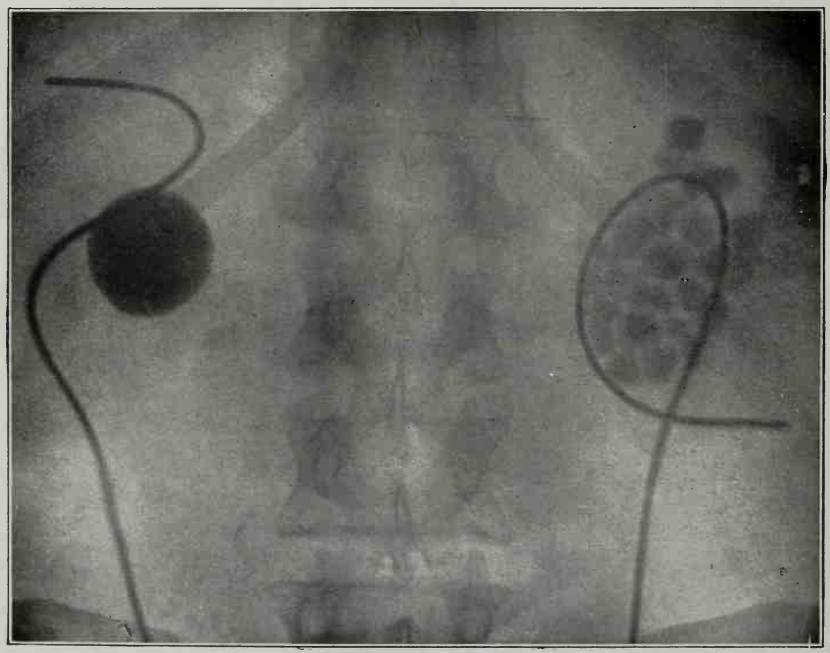

FIG. 173.—Unusual types of kidney stones. The faceted stones in the right suggest gall-stones, but the position and wide curve of the catheter prove they are in the kidney pelvis.

kidney distended by back pressure with stones separated by fluid. Large dendritic stones mean that the kidney has suffered severely.

Shadows which may be confused with stones are: (1) Those due to material in the bowel, fecal masses, fruit pits, enteroliths, opaque salts, such as bismuth and barium (particularly residues in diverticulæ of the colon), Blaud's pills, salol capsules. The appendix often lies in close relation to the right ureter and foreign bodies or enteroliths within it may be mistaken for ureteral calculi. (2) Gall-stones which can usually be differentiated by their structure and shifting position with reference to the kidney area on plates taken in the anterposterior and postero-anterior diameters. (3) Calcified glands which have a spongy appearance usually sufficient to identify them. They occur along the course of the root of the mesentery, in a line from the left kidney to the right sacro-iliac, and in the neighborhood of the iliac vessels they may be identified by their shifting position. (4) Tuberculous foci in the kidneys may calcify and give shadows resembling those of stone. (5) Calcification in tumor masses in the pancreas, or about the kidney may be a rare cause of confusion. (6) The tip of a transverse process may be so much more dense than the body that it may suggest a stone. (7) Small areas of density in the spleen may overlie the upper portion of the kidney. (8) Calcification in a blood clot or about a foreign body may simulate a stone if it overlies the kidney. (9) Mention must also be made of the shadows cast by fibromata, scars and even dressings on the back which may be recorded on the plate as areas of increased density. (10) Artefacts in plates due to thin spots in the emulsion or small areas which are unequally developed may be a source of confusion.

Pyelography.—Pyelography is not a procedure to be undertaken without due consideration and caution. Severe reactions cannot be entirely avoided although a careful technic will do much to prevent them. The most important single precaution to be observed is to allow the solution to flow in slowly under a slight gravity pressure and to stop as soon as the patient complains of pain in the kidney. Observation of the fluid level in the container from which the solution is flowing is helpful. As the pelvis becomes filled the level becomes stationary.

The outline of the kidney pelvis as obtained by this method varies greatly. The normal pelvis is somewhat lily-shaped with the ureter corresponding to the stem. The pelvis presents a more or less rounded border, into which the ureter blends on the inner

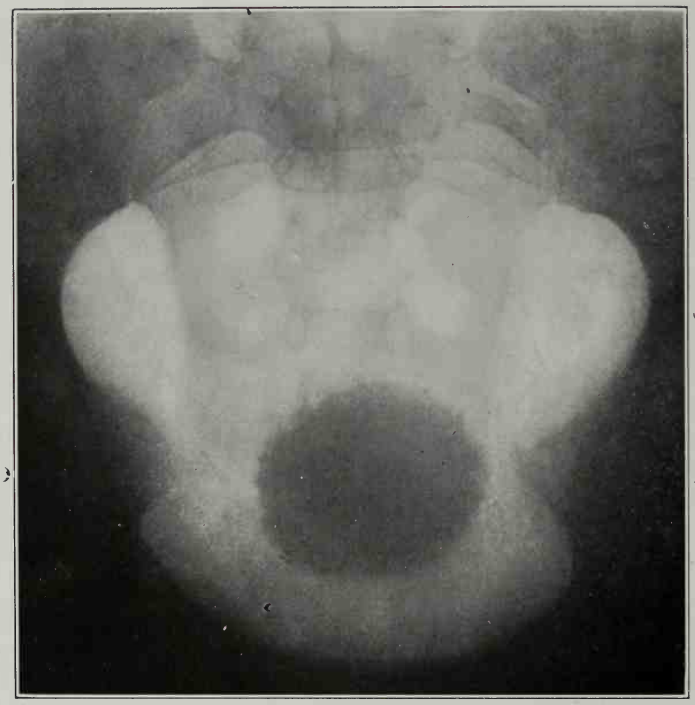

FIG. 174.—Large stone in the urinary bladder.

FIG. 175.—Injected kidney pelves. The abnormal shape is due to anatomical variation.

margin. Arising from its outer edge are a variable number of processes projecting into the kidney substance (major calices) from the tips of which arise small further projections called minor calices. The pelvis may be more or less globular, bell shaped or consist entirely of two or more branches.

FIG. 176.—Hydronephrosis, demonstrated by injection with thorium.

Incomplete filling of the pelvis is usually the result of spasm of the ureter or pelvis commonly produced by too rapid distention with the opaque medium. Pressure from enlarged neighboring organs and extra renal tumors may also prevent complete filling. The plate may show no solution in the kidney, a small irregular hazy shadow or what appears to be a markedly deformed pelvis. Reëxamination with more gentle technic will ordinarily demonstrate a normal pelvis.

The mobility of the kidney may be determined by examination

after pyelography in the supine and erect positions. This examination may be extremely useful in the determination of ureteral kinks.

Anomalies.—Aberrant positions of the kidneys and multiple ureters are perhaps best brought out by this method which is more accurate than plain roentgenography with or without opaque catheter.

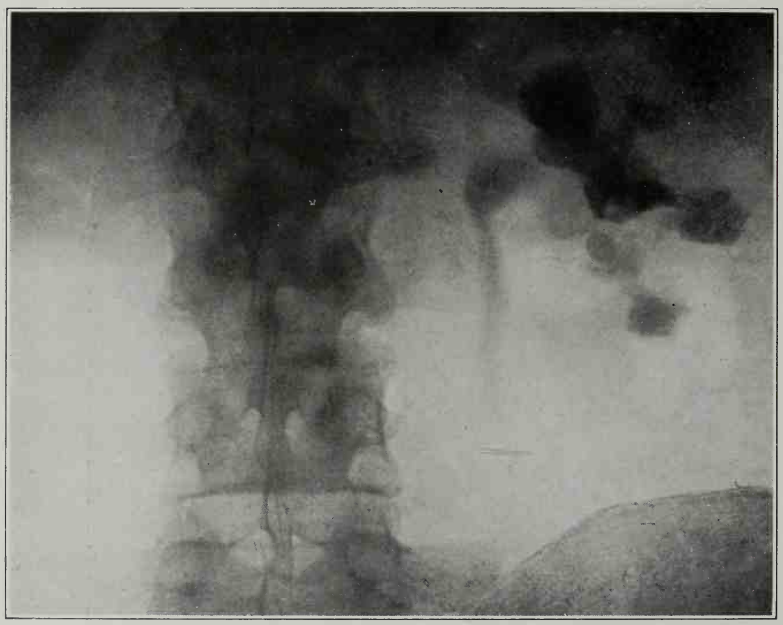

FIG. 177.—The injected pelvis of an infected kidney.

Hydronephrosis.—Hydronephrosis shows all degrees of change from blunting of the minor calices to the formation of a large sac, depending upon the site of the obstruction and the length of its existence. With obstruction near the kidney the characteristic early change is blunting of the minor calices. With obstruction near the bladder, on the other hand, dilatation of the pelvis and a certain amount of rounding of its outline is the characteristic finding. In the later stages of the process both major and minor calices may disappear and the opaque solution collect in one large pool in the sac which is all that remains of the kidney. At times such a sac may have several pockets, each one of which collects a pool of

solution. The condition may not be obvious in the routine supine position; but with the patient erect, each pocket shows a fluid level.

The plates may also give an indication of the cause of the condition, such as stone in the ureter, kinks or dilatations. It is possible to estimate roughly the amount of kidney damage from the amount of solution the pelvis will hold. Anything under 20 c.c. may be considered normal.

Pyonephrosis.—In inflammatory conditions the chief change is in the major calices which are apt to have irregular, moth-eaten edges and to be increased in length and width. In the later stages they may show rounded dilatations at their extremities. The form of the pelvis varies according to the amount of destruction of the kidney substances and the degree of distention of the pelvis. Ordinarily the pelvis is contracted rather than dilated.

Tuberculosis.—The early stages of tuberculosis are invisible or indistinguishable from pyonephrosis. In the caseocavernous type the picture is characteristic. The pelvis is dilated, often irregular, and is surrounded by masses of opaque solution scattered through the parenchyma representing excavations. These cavities may appear to be free from the pelvis or be connected to it by an occasional narrow isthmus.

The ureter is usually also involved. It becomes dilated and tortuous and may show strictures.

Plain plates without pyelography will at times record irregularly calcified caseous areas.

Tumors.—The deformity produced in the pelvis depends upon the size and location of the growth. The characteristic picture is an obliteration of a portion of the pelvis and its corresponding calices. A localized enlargement of the kidney shadow may be made out, particularly if the lower pole is involved. When the whole kidney is involved the pelvis may be reduced to a small mass with irregular strands of opaque material stretching out from it into an enlarged kidney area. This latter type of growth should not be confused with polycystic kidneys where a similar appearance is found. Due to the pressure of multiple cysts throughout the parenchyma the calices are converted into long finger-like processes stretching out from the pelvis which may be somewhat encroached upon. Usually the rounded impressions of the cysts can be made out upon the calices and pelvis and the process is practically always bilateral. Solitary cysts are invisible when small, and when large may simulate tumor by compressing a portion of the pelvis and its calices.

Pressure upon the kidney from enlarged organs or tumors in its vicinity may by compression prevent complete filling of the pelvis and simulate tumor. Extranephric masses may displace or distort the ureter.

Stones in the pelvis or calices produce an intensification in the shadow. Pyelography may give invisible stones an opaque coating which permits their recognition.

Papillomata.—Papillomata produce rounded holes in the shadow of the pelvis.

URETERS.

The course and condition of the ureters may be well outlined provided they can be kept filled with thorium during exposure. This may be a somewhat difficult matter in the normal ureter if the catheter is too small to occlude the lower end. Injection has these advantages over the use of radiographic catheters: the ureter lies in its true course and does not conform to that of the rather rigid catheter, and changes in diameter and irregularities in outline are well brought out. Apparent kinking due to the angulation in the ureter produced at the tip of the catheter does not occur, whereas true kinks are readily recognizable. Abnormalities are fairly common, as has already been mentioned, consisting of multiple ureters. Irregularities in outline are usually the result of infection, most commonly of tuberculous origin which usually appears first in the lower portions of its course. Dilatations may be true diverticula which contain stones or the enlargement above an obstruction as a result of pressure from tumors or adhesions, the latter being particularly common following infections of the vas deferens in the male and pelvic cellulitis in the female.

The course of the ureter is downward across the transverse processes of the lumbar vertebræ and sacro-iliac joints to the pelvis, then curving inward and forward toward the bladder. There are four points of narrowing where stones are prone to lodge: (1) the ureteropelvic junction, (2) where they cross the iliac vessels, (3) just outside the bladder, (4) the papilla within the bladder. Stones will be found most commonly at (1) and (3). They are easily overlooked when lodged near the iliac vessels, because their shadow is projected upon that of the sacrum. They may be projected free of the sacrum by an increased tilt of the tube. The shadows of ureteral calculi are oval or elongated and are irregular in outline and density. Their long axis lies in the direction of the course of the

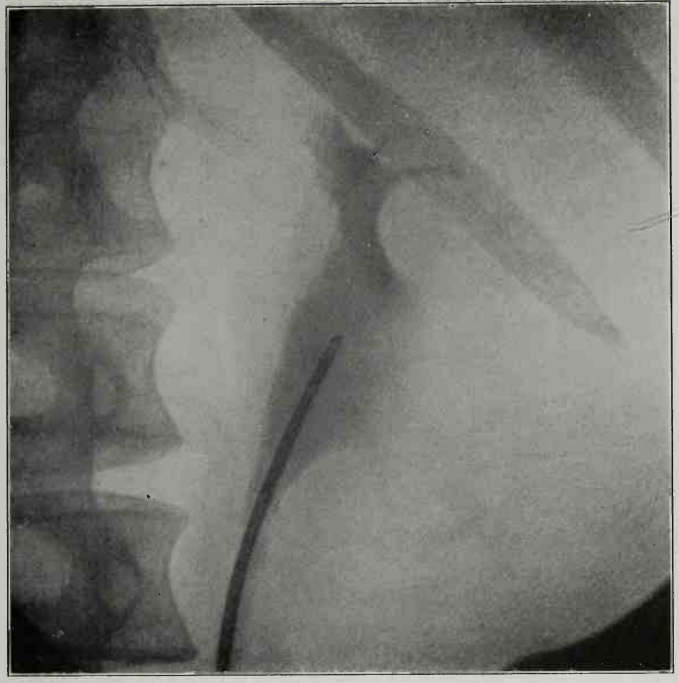

FIG. 178.—Tumor of lower half of kidney. Hypernephroma. Note suppression of lower half of pelvis and corresponding calices.

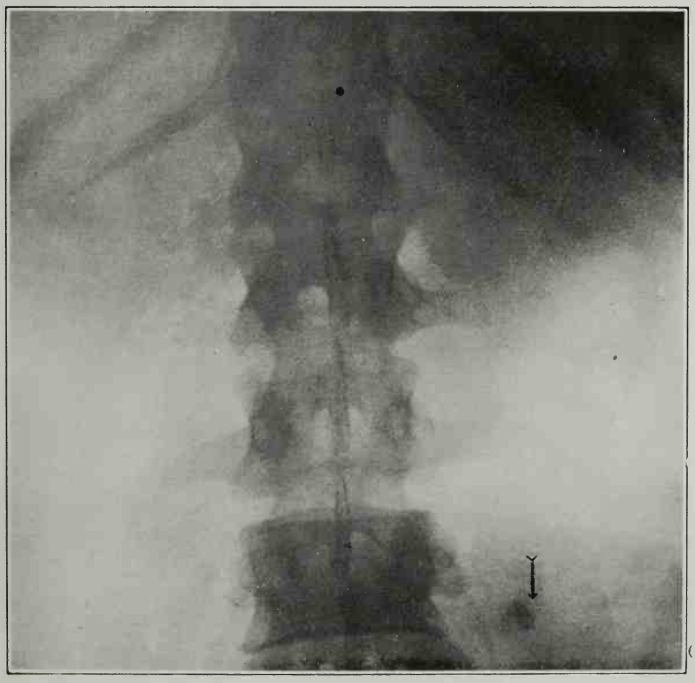

FIG. 179.—A calcified mesenteric gland suggesting a stone in the ureter.

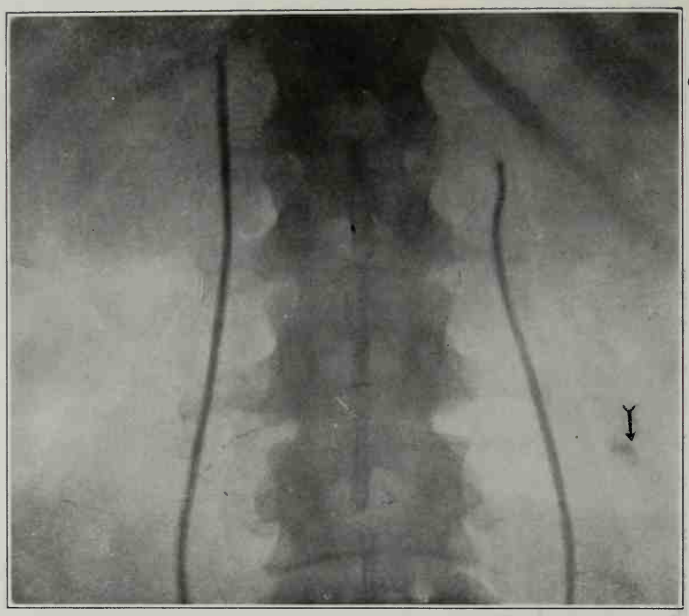

FIG. 180.—The same case as Fig. 179. The radiographic catheter demonstrates that the shadow is well outside the course of the ureter.

FIG. 181.—Large stone in dilated ureter. The catheter is obstructed. The dilated ureter is made visible by the injection of thorium.

ureter. Shadows which may be confused with them, in addition to those enumerated before, are hypertrophic changes upon the vertebræ or pelvic bones, arteriosclerosis of the pelvic arteries, calcified fibroids, calcified ovaries, dermoid cysts and phleboliths. Phleboliths are small, circular or oval, sharply outlined calcifications, usually multiple, which occur in the pelvis in the region of the ischial tuberosities. They are calcified thrombi on the distal side of the valves in the plexus of veins in the pelvic cellular tissue about the bladder and rectum. They are very common and are constantly being mistaken for ureteral calculi. The distinguishing characteristics of a calculus are that it is not so sharply outlined, that it is more apt to be oval than round, and that it lies in the course of the ureter which passes above and internal to the area where phleboliths lie. Furthermore, phleboliths seldom occur singly.

In case of doubt the patient should be examined with an opaque catheter in the ureter, preferably stereoscopically, in order to determine the presence or absence of obstruction as well as the relation of the suspected shadow to the ureter.

BLADDER.

The outline of the partially filled bladder may be made out in many pelvic plates but may be readily visualized by filling it with air or opaque solution. Stones in the bladder are occasionally missed because a large percentage of them are urates. Important characteristics of bladder stones are that they are of fairly large size, are oval, sometimes laminated, and lie with their long axis transversely in the pelvis.

The bladder may be outlined by opaque solutions or by air. Large diverticula are usually well brought out by moderate distention with opaque liquids or solution followed by partial removal of the fluid and inflation with air. They appear as knobs on either side or behind the main shadow and may be larger than the bladder itself. Trabeculation of the bladder wall is sometimes suggested by irregularity of the outline, particularly along the sides. In some cases, particularly of tuberculosis, distention of the bladder may cause the solution to run up a dilated, irregular ureter and visualize it and the kidney pelvis in cases where catheterization is impossible. In children where it is difficult to catheterize the ureters, they may sometimes be similarly filled by distention of the bladder in cases of obstruction at the neck of the

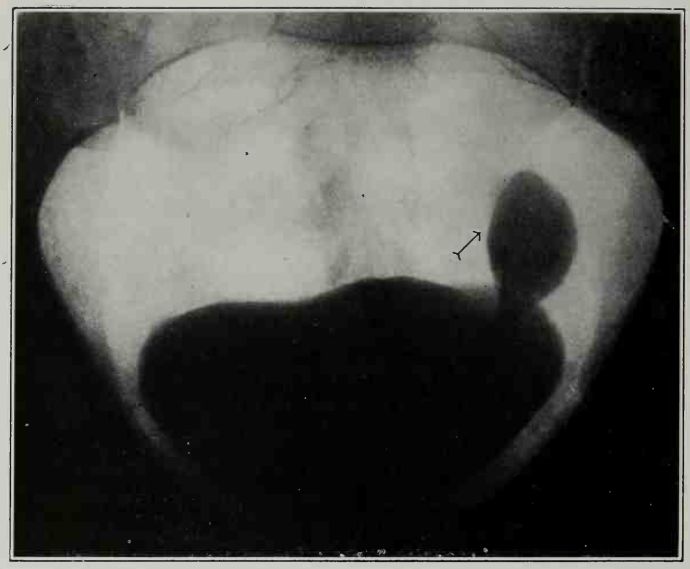

FIG. 182.—Diverticulum of the bladder, demonstrated by filling the bladder with opaque solution.

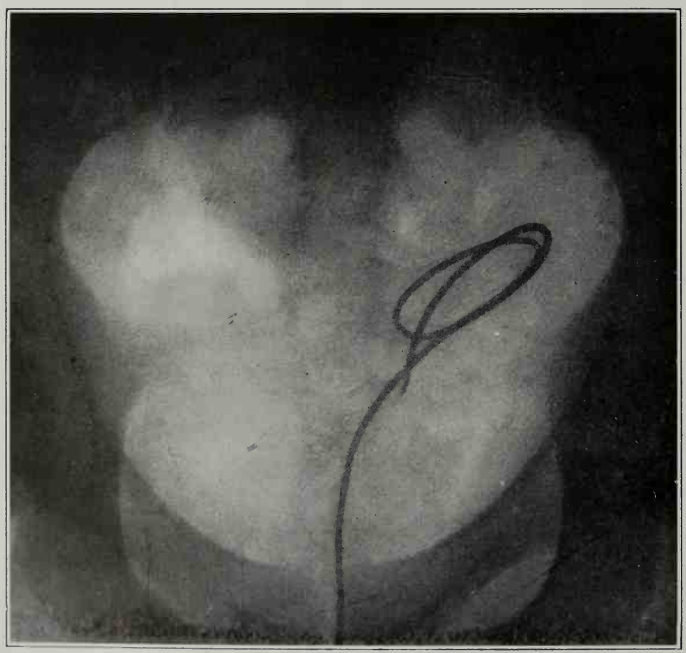

FIG. 183.—Diverticulum of the bladder, demonstrated by means of the radiographic catheter.

bladder due to congenital valves in the region of the verumontanum. Congenital anomalies are sometimes encountered, such as hour-glass bladder and patent urachus which gives a thin line of solution extending upward toward the umbilicus.

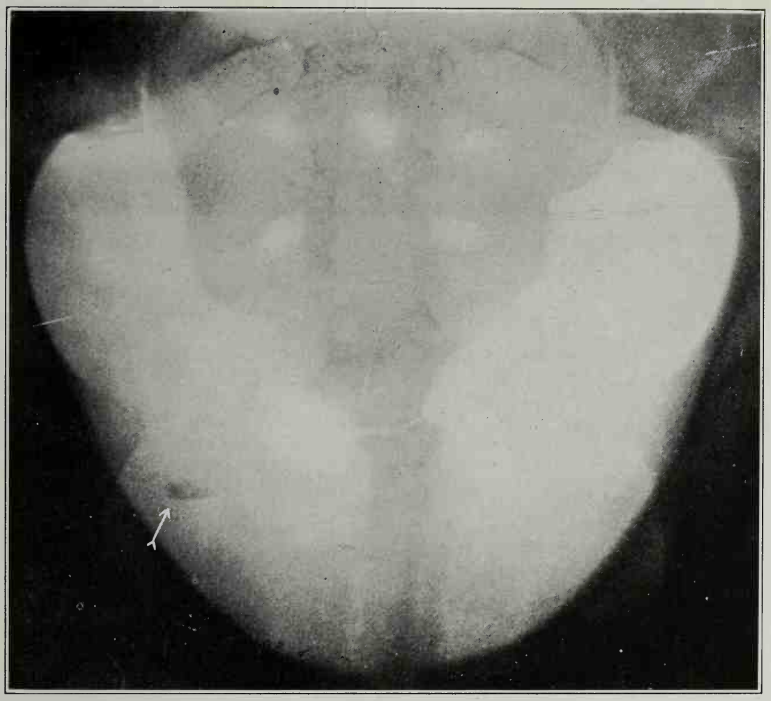

FIG. 184.—Small stone in the lower end of the ureter. Its transverse position shows that it is near the mouth of the ureter.

Tumors may be extensive enough to produce defects in the thorium shadow, although it is unusual. A better method for their demonstration, which is equally useful in the case of stone, is to inflate the bladder with air and secure stereoscopic plates. Hypertrophied prostates may be well outlined by inflating both the bladder and the rectum with air. Bladder tumors may become evident through calcification occurring within them.

MALE GENITALS.

Small multiple calculi occur in the prostate and may be mistaken for urinary concretions. The vas deferens and seminal vesicles,

when injected with opaque solution, may show a certain amount of distortion as a result of inflammation.

FEMALE GENITALS.

Calcification is often seen in fibroids in the form of round, irregularly calcified masses, often multiple and occupying any portion of the pelvis. In rare cases the ovaries may be calcified. They are oval, flattened, spongy masses suggesting glands lying internal to and above the ischium. They may be mistaken for ureteral stones. Attempts have been made to inject the uterus and tubes with opaque solution but the technic is still undeveloped. With pneumoperitoneum it is possible to outline the uterus, tubes and the ovaries.

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